

Piezoelectric Ceramic Sensors (PIEZOTITE®)

PIEZOELECTRIC
CERAMICS
SENSORS
(PIEZOTITE®)



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*Innovator
in Electronics*

Murata
Manufacturing Co., Ltd.

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Preface

Recently, with the remarkable advance of electronics technology, various new products have come into existence. Until this time, the effect of electronics was seen most clearly in television, radio and other communications equipment, but as semiconductor technology, and computer technology advance, the range of electronics' effect on our lives has increased dramatically. In particular, sensor technology and the greater intelligent functions of today's microcomputers have served as a basis for the trend toward combining electronics and mechanics into what is called mechatronics.

It is not merely the equipment itself, however, that has made all this possible. Within the equipment are highly sophisticated components with unique functions which can translate electrical to mechanical energy and mechanical to electrical energy and which play a large role in today's equipment modernization and advance. These are piezoelectric components. This catalog briefly introduces the basics of piezoelectric ceramics, Murata's piezoelectric ceramic materials, piezoelectric transducers and other products.

Please insure the component is thoroughly evaluated in your application circuit.

In case that the component is not mentioned in our statement, please contact your Murata representative for details.

CONTENTS

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Preface

| | | |
|----------|--|----|
| 1 | Introduction | 2 |
| 2 | Characteristics of Piezoelectric Ceramics (PIEZOTITE®) | 3 |
| | 1. Resonant Frequency and Vibration Mode | 3 |
| | 2. Piezoelectric Material Constant Symbols | 6 |
| | 1 Frequency Constant N | 6 |
| | 2 Piezoelectric Constants d and g | 6 |
| | 3 Electromechanical Coupling Coefficient k | 6 |
| | 4 Mechanical Qm | 6 |
| | 5 Young's Modulus Y ^E | 7 |
| | 6 Poisson's Ratio σ ^F | 7 |
| | 7 Density ρ | 7 |
| | 8 Relative Dielectric Constant $\frac{\epsilon^T}{\epsilon_0}$ | 7 |
| | 9 Curie Temperature T _c | 7 |
| | 10 Coercive Field E _c | 7 |
| 3 | Murata's Piezoelectric Ceramics (PIEZOTITE®) Material | 8 |
| | 1. Characteristics of Typical Materials | 8 |
| | 2. Features of PIEZOTITE® Materials | 9 |
| | 3. Temperature Characteristics and Aging | 9 |
| 4 | Murata's Piezoelectric Ceramic Resonators (PIEZOTITE®) | 10 |
| | 1. Shapes | 10 |
| | 2. Standard Specification Models | 10 |
| | 3. Notice | 11 |
| 5 | Piezoelectric Ceramic (PIEZOTITE®) Applications | 12 |
| | Piezoelectric Actuator | 13 |
| | Molded Underwater Transducer | 17 |
| | Ultrasonic Sensor | 18 |
| | Shock Sensor | 26 |
| | Knocking Sensor Elements | 37 |
| | Ultrasonic Bubble Sensor | 38 |
| | Electric Potential Sensor | 39 |

1 Introduction

2 Characteristics of Piezoelectric Ceramics (PIEZOTITE®)

3 Murata's Piezoelectric Ceramics (PIEZOTITE®) Material

4 Murata's Piezoelectric Ceramics Resonators (PIEZOTITE®)

5 Piezoelectric Ceramic (PIEZOTITE®) Applications

1 Introduction

1. What are Piezoelectric Ceramics?

Piezoelectric ceramics are known for what are called the piezoelectric and reverse piezoelectric effects. The piezoelectric effect causes a crystal to produce an electrical potential when it is subjected to mechanical vibration. In contrast, the reverse piezoelectric effect causes the crystal to produce vibration when it is placed in an electric field. Of piezoelectric materials, Rochelle salt and quartz have long been known as single-crystal piezoelectric substances. However, these substances have had a relatively limited application range chiefly because of the poor crystal stability of Rochelle salt and the limited degree of freedom in the characteristics of quartz. Later, barium titanate (BaTiO_3), a piezoelectric ceramic, was introduced for applications in ultrasonic transducers, mainly for fish finders. More recently, a lead titanate, lead zirconate system ($\text{PbTiO}_3\text{-PbZrO}_3$) appeared, which has electromechanical transformation efficiency and stability (including temperature

characteristics) far superior to existing substances. It has dramatically broadened the application range of piezoelectric ceramics. When compared with other piezoelectric substances, both BaTiO_3 and $\text{PbTiO}_3\text{-PbZrO}_3$ have the following advantages:

■ Advantages

- ① High electromechanical transformation efficiency.
- ② High machinability.
- ③ A broad range of characteristics can be achieved with different material compositions (high degree of freedom in characteristics design).
- ④ High stability.
- ⑤ Suitable for mass production, and economical.

Murata, as a forerunner in the piezoelectric ceramic industry, offers an extensive range of products with piezoelectric applications.

2. Properties of Piezoelectric Ceramics

Piezoelectric ceramics are a type of multi-crystal dielectric with a high dielectric constant and are formed by two processes: first, high temperature firing. After firing, they have the characteristic crystal structure shown in Fig. 1 (a) but do not yet exhibit the piezoelectric property because the electrical dipoles within the crystals are oriented at random and the overall moment of the dipoles is canceled out. To make ceramics piezoelectric they must be polarized. A DC electric field of several kV/mm is applied to the piece of ceramic to align the internal electrical dipoles in a single orientation (see Fig. 1 (b)). Due to the strong dielectric property of the ceramic, the dipole moment remains unchanged after the electric field is removed, and the ceramic thus exhibits a strong piezoelectric property (see Fig. 1 (c)). When an AC signal is applied to a piezoelectric ceramic (piezoelectric transducer) in a frequency matching the specific elastic frequency of the ceramics (which depends on the shape of the material), the ceramic exhibits resonance. Since the ceramic has a very high electromechanical transforming efficiency at the point of

resonance, many applications use this resonance point. Also piezoelectric ceramics when molded in certain shapes have more than one point of resonance depending on vibration mode. In such a case, the vibration mode most suited for the application is selected.

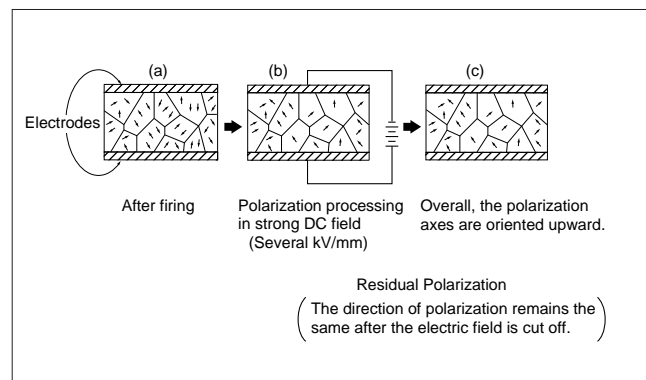


Fig. 1 Polarization Processing of Piezoelectric Ceramics

3. Application of Piezoelectric Ceramics

Product applications for piezoelectric ceramics include the following categories:
 Murata has and is continuing to direct extensive research development efforts to the entire range of applications of piezoelectric ceramics listed in the right side. It is expected that the applications of piezoelectric ceramics will continue to extend into a broader range of industries as new piezoelectric materials are created.
 This application manual concentrates on applications with mechanical power sources and sensors which are now finding broader applications.

■ Piezoelectric Applications

- ① Mechanical power sources (electrical-to-mechanical transducers):
Piezoelectric actuators, piezoelectric fans, ultrasonic cleaners, etc.
- ② Sensors (mechanical-to-electrical transducers):
Ultrasonic sensors, knocking sensors, shock sensors, acceleration sensors, etc.
- ③ Electronic circuit components (transducers):
Ceramic filters, ceramic resonators, surface acoustic wave filters, microforks, etc.

2 Characteristics of Piezoelectric Ceramics (PIEZOTITE®)

For using piezoelectric ceramics, it is important to first have an adequate knowledge of the properties of different piezoelectric materials before choosing a suitable type for

a specific application. The following sections describe the major characteristic which need to be evaluated to determine the properties of piezoelectric ceramic materials.

1. Resonant Frequency and Vibration Mode

If an AC voltage of varying frequency is applied to a piezoelectric ceramic (piezoelectric transducer) of a certain shape, it can be seen that there is a specific frequency at which the ceramic produces a very strong vibration. This frequency is called the resonant frequency, f_r , and depends on the ceramic's specific elastic vibration (resonance) frequency, which is a function of the shape of the material.

Piezoelectric ceramics have various vibration modes (resonant modes) which depend on their shape, orientation of polarization, and the direction of the electric field. Each of these vibration modes have unique

resonant frequencies and piezoelectric characteristics. Fig. 2 shows typical vibration modes in relation to the shapes of ceramic materials, the resonant frequency in each vibration mode, and the material constant symbols. In Fig. 2, the piezoelectric material constant symbols have the following meanings:

- N** : Frequency Constant (described in Section 1).
- d** : Piezoelectric Distortion Constant (described in Section 2).
- g** : Voltage Output Constant (described in Section 2).
- k** : Electromechanical Coupling Coefficient (described in Section 3).
- Y^E** : Young's Modulus (described in Section 5).
- ϵ^T** : Dielectric Constant (described in Section 8).

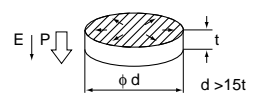
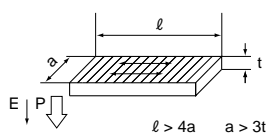
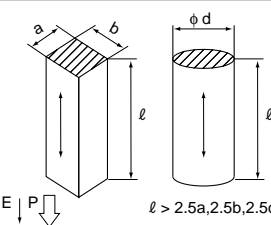
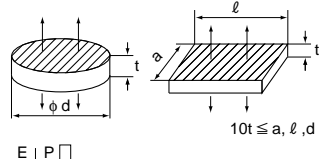
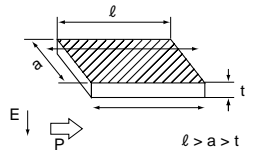
| Vibration Mode | Shape/Vibration Mode | Resonant Frequency (f_r) | Material Constant Symbol | | | | | |
|-------------------|--|------------------------------|--------------------------|----------|----------|------------|-------------------|----------|
| | | | k | d | g | Y^E | ϵ^T | N |
| Radial Mode |  <p>P : Direction of polarization E : Direction of electric field</p> <p>Thin disk with radial vibration mode. Polarization is oriented along the thickness of the disk.</p> | $\frac{N_p}{d}$ | k_p | d_{31} | g_{31} | Y_{11}^E | ϵ_{33}^T | N_p |
| Length Mode |  <p>Thin rectangular plate, with the direction of vibration orthogonal to the polarization axis and with a single point of resonance.</p> | $\frac{N_{31}}{l}$ | k_{31} | d_{31} | g_{31} | Y_{11}^E | ϵ_{33}^T | N_{31} |
| Longitudinal Mode |  <p>Square and cylindrical columns. Vibration is oriented along the direction of polarization. Only a single point of resonance.</p> | $\frac{N_{33}}{l}$ | k_{33} | d_{33} | g_{33} | Y_{33}^E | ϵ_{33}^T | N_{33} |
| Thickness Mode |  <p>Disk and rectangular plates which are thin compared to their surface areas. They have multiple points of resonance in longitudinal vibration mode.</p> | $\frac{N_t}{t}$ | k_t | d_{33} | g_{33} | Y_{33}^E | ϵ_{33}^T | N_t |
| Shear Mode |  <p>Disk or rectangular plates, with the electric field orthogonal to the direction of polarization, causing a shear vibration along the surface.</p> | $\frac{N_{15}}{t}$ | k_{15} | d_{15} | g_{15} | Y_{44}^E | ϵ_{11}^T | N_{15} |

Fig. 2 Typical Vibration Modes, Resonant Frequencies, and Material Constant Symbols of Piezoelectric Ceramics

2 Characteristics of Piezoelectric Ceramics (PIEZOTITE®)

When a piezoelectric material is subjected to stress T , it produces polarization P which is a linear function of T : $P=dT$ (d : piezoelectric strain constant). This effect is called the normal piezoelectric effect. In contrast, when a piezoelectric substance has an electric field E applied across its electrodes, it produces distortion S which is a linear function of the electric field : $S=dE$. This effect is called the reverse piezoelectric effect. For an elastic material, the relationship of distortion S to the stress T is given by $S=s^E T$ (s^E : compliance); for a dielectric substance, the relationship of electrical displacement D with electric field strength E is given by $D=\epsilon E$. For a piezoelectric ceramic, these relationships are given by the following equations, both being associated with piezoelectric strain constants :

$$\left. \begin{aligned} S_i &= s_{ij}^E T_j + d_{mi} E_m \\ D_n &= d_{nj} T_j + \epsilon_{nm}^T E_n \end{aligned} \right\} \dots\dots (1)$$

$(m, n = 1, 2, 3 ; i, j = 1, 2, \dots, 6)$

These equations are called the basic piezoelectric equations (type d), where the electric field E and electrical displacement D are represented in vector magnitudes ; whereas stress T and distortion S are given in symmetrical tensile magnitudes. When the symmetry of the crystals is taken into account, Eq. (1) is simplified because some constants in the equations are nullified and some other constants become equal to a third set of constants.

With piezoelectric ceramics, when the polarization axis is placed along the z (3) axis and two arbitrary orthogonal axes (which are also orthogonal to the z axis and assumed to be the x (1) and y (2) axis), the crystal structure of the ceramic can be represented in the same way as that of 6mm crystals, in which case the only independent non-zero coefficients are the following ten constants :

$$s_{11}^E \left(\frac{1}{Y_{11}^E} \right), s_{12}^E \left(\frac{1}{Y_{12}^E} \right), s_{13}^E \left(\frac{1}{Y_{13}^E} \right), s_{33}^E \left(\frac{1}{Y_{33}^E} \right), s_{44}^E \left(\frac{1}{Y_{44}^E} \right),$$

$$d_{31}, d_{33}, d_{15}, \epsilon_{11}^T, \epsilon_{33}^T,$$

For example, the basic piezoelectric equations for longitudinal vibration of a rectangular ceramic strip is given by the following equations :

$$\left. \begin{aligned} S_1 &= s_{11}^E T_1 + d_{31} E_3 \\ D_3 &= d_{31} T_1 + \epsilon_{33}^T E_3 \end{aligned} \right\} \dots\dots (2)$$

A piezoelectric ceramic transducer can be represented by an equivalent circuit which is derived from the basic piezoelectric equations representing its vibration mode. The circuit is called Maison's equivalent circuit. More generally, the equivalent circuit, as shown in Fig. 3, may be used to represent a piezoelectric ceramic. In this equivalent circuit, the serial resonant frequency f_s , and parallel resonant frequency f_p are given by the following equations :

$$\left. \begin{aligned} f_s &= \frac{1}{2 \pi \sqrt{L_1 C_1}} \\ f_p &= \frac{1}{2 \pi \sqrt{L_1 \cdot \frac{C_1 C_0}{C_1 + C_0}}} \end{aligned} \right\} \dots\dots (3)$$

Constants f_s and f_p are necessary to determine the electro-mechanical coupling coefficient k .

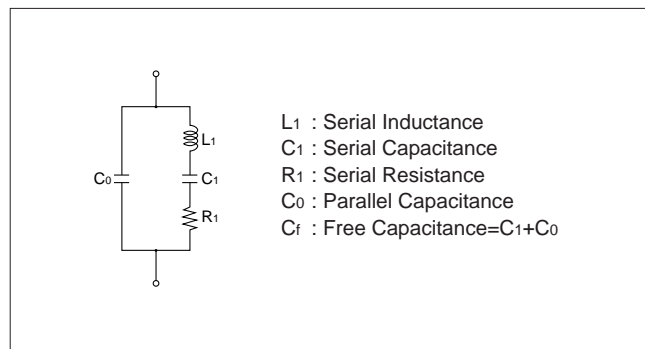


Fig. 3 Equivalent Circuit for Piezoelectric Ceramic Transducer

- L_1 : Serial Inductance
- C_1 : Serial Capacitance
- R_1 : Serial Resistance
- C_0 : Parallel Capacitance
- C_f : Free Capacitance= C_1+C_0

Strictly speaking, the resonant frequency can be defined in the following three ways :

- (1) Serial resonant frequency f_s of the equivalent serial circuit for a piezoelectric ceramic transducer.
- (2) Lower resonance frequency f_r , the lower of the two frequencies, where the cross-electrode admittance or impedance of the piezoelectric ceramic transducer is in the null phase.
- (3) Maximum admittance frequency f_m where the cross-electrode admittance of the piezoelectric ceramic transducer is maximized (impedance minimized).

However, the differences between the three frequencies, f_s , f_r , and f_m , is so small that it is negligible. In actual cases, therefore, when we measure frequency f_m , it can be called resonant frequency f_r . Also, the minimum admittance frequency f_n may be called antiresonant frequency f_a . The resonant frequency f_r can be measured with either of the following two circuits :

Characteristics of Piezoelectric Ceramics (PIEZOTITE®) 2

■ Measuring Method Using Constant Voltage Circuit

The f_r measuring circuit using a constant voltage source is shown in Fig. 4.

The oscillator Osc and input resistors R_1 and R_2 are used to apply a constant voltage signal to the piezoelectric ceramic transducer. The current passing through the transducer is measured across output resistor R_2 .

If the transducer's impedance is much greater than R_2 , the voltmeter reading is proportional to the transducer's admittance. The frequency where the voltmeter reading is maximized is the resonant frequency f_r , and the frequency where the reading is minimized is the antiresonant frequency f_a .

Variable resistor R_v is used to determine the resonant resistance R_1 , which is needed to calculate the mechanical Q_m .

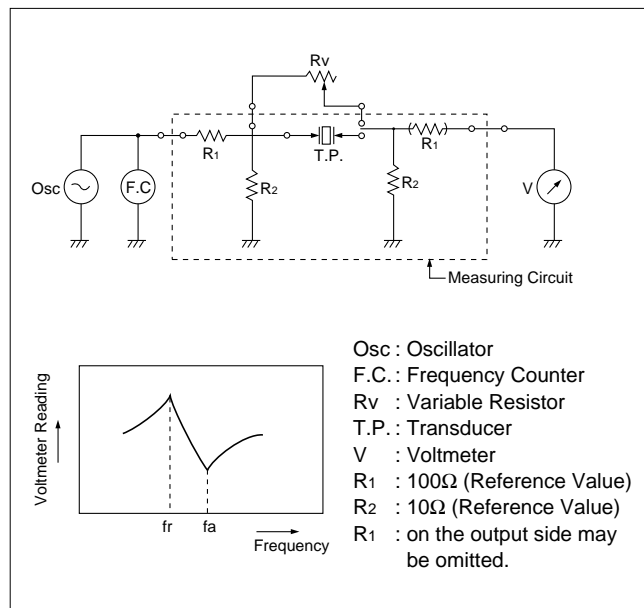


Fig. 4 Resonant Frequency Measuring Method Using Constant Voltage Circuit

■ Measuring Method Using Constant Current Circuit

The f_r measuring circuit using a constant current source is shown in Fig. 5. Resistor R_3 regulates the current passing through the piezoelectric ceramic transducer. If R_3 is much greater than the transducer's impedance, the voltmeter reading is proportional to the transducer's impedance. The frequency where the voltmeter reading is minimized is the resonant frequency f_r , and the frequency where the reading is maximized is the antiresonant frequency f_a .

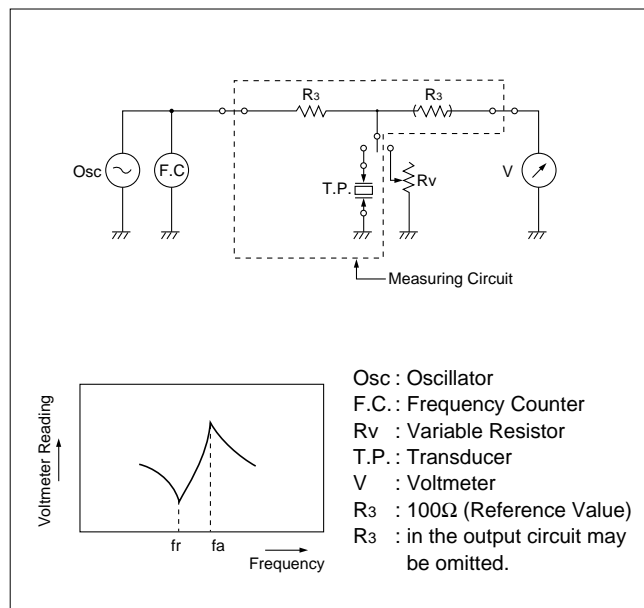


Fig. 5 Resonant Frequency Measuring Circuit Using Constant Current Circuit

2

2 Characteristics of Piezoelectric Ceramics (PIEZOTITE®)

2. Piezoelectric Material Constant Symbols

1 Frequency Constant N

The velocity of sound that propagates through a piezoelectric ceramic has a specific value in each vibration mode when the resonance of other vibration modes is not in the vicinity. For a piezoelectric ceramic with a certain shape, the relationship of wavelength λ of a vibration with propagation length ℓ at the resonant point is given by equation (4). Because the sound velocity is constant, we obtain the following equations (5) and (6) :

$$\frac{\lambda}{2} = \ell \dots\dots\dots (4)$$

$$v = fr \cdot \lambda \dots\dots\dots (5)$$

$$fr \cdot \ell = \frac{v}{2} = N \text{ (Hz} \cdot \text{m)} \dots\dots\dots (6)$$

where N is the frequency constant. The frequency constant depends on the vibration mode. The resonant frequency may also be determined by the equation, $fr = N / \ell$ as shown in Fig. 2.

2 Piezoelectric Constants d and g

① Piezoelectric Distortion Constant d

Piezoelectric distortion constant is the distortion resulting from the application of an electric field of uniform strength with no stress. It is given by equation (7) :

$$d = k \sqrt{\frac{\epsilon^T}{Y^E}} \text{ (m/V)} \dots\dots\dots (7)$$

where ϵ^T : Dielectric constant

Y^E : Young's modulus (N/m²)

k : Electromechanical coupling coefficient

$$d_{31} = k_{31} \sqrt{\frac{\epsilon_{33}^T}{Y_{11}^E}}, d_{33} = k_{33} \sqrt{\frac{\epsilon_{33}^T}{Y_{33}^E}}, d_{15} = k_{15} \sqrt{\frac{\epsilon_{11}^T}{Y_{44}^E}} \dots\dots\dots (8)$$

② Voltage Output Coefficient g

Voltage output coefficient refers to the field strength which results from a uniform stress applied under no electrical displacement. It is given by equation (9) :

$$g = \frac{d}{\epsilon^T} \text{ (V} \cdot \text{m/N)} \dots\dots\dots (9)$$

$$g_{31} = \frac{d_{31}}{\epsilon_{33}^T}, g_{33} = \frac{d_{33}}{\epsilon_{33}^T}, g_{15} = \frac{d_{15}}{\epsilon_{11}^T} \dots\dots\dots (10)$$

Constants d and g depend on the vibration mode, and the constants in each vibration mode are given by the subscripted symbols shown in Fig. 2.

Displacements generated under an electric voltage or a voltage generated under force can be determined by constants d and g. For example, the displacement $\Delta \ell$ caused by voltage V applied across the electrodes in the lengthwise vibration mode is given by :

$$\frac{\Delta \ell}{\ell} = d_{31} \cdot \frac{\ell}{t} V \dots\dots\dots (11)$$

Conversely, the voltage V caused by force F applied along the direction of vibration is given by :

$$V = g_{31} \cdot \frac{1}{a} F \dots\dots\dots (12)$$

3 Electromechanical Coupling Coefficient k

The electromechanical coupling coefficient is a constant representing the piezoelectric efficiency of a piezoelectric ceramic. More specifically, it represents the efficiency of converting electrical energy (applied across the electrodes of a piezoelectric ceramic) into mechanical energy, and it is defined as the root mean square of the energy accumulated within the crystal in a mechanical form. This accumulated energy reflects the total electrical input.

$$\text{Electromechanical Coupling Coefficient} = \sqrt{\frac{\text{Accumulated Mechanical Energy}}{\text{Supplied Electrical Energy}}}$$

The electromechanical coupling coefficient depends on the vibration mode, as shown in Fig. 2. It is determined by the following equations using the resonant frequency fr, anti-resonant frequency fa, and their difference $\Delta f = fa - fr$.

① Radial Vibration of Disk Transducer

$$\frac{kp^2}{1 - kp^2} = \frac{(1 - \sigma^E) J_1 \{ \psi_1 (1 + \Delta f / fr) \} - \psi_1 (1 + \Delta f / fr) J_0 \{ \psi_1 (1 + \Delta f / fr) \}}{(1 + \sigma^E) J \{ \psi_1 (1 + \Delta f / fr) \}} \dots\dots\dots (13)$$

where J_0, J_1 : Type 1 vessel functions of the 0th and 1st dimensions

σ^E : Poisson's ratio

ψ_1 : Lowest dimension of positive root of $(1 - \sigma^E) J_1(\psi) = \psi J_0(\psi)$

If kr is relatively small, equation (13) may be approximated as follows :

$$kp^2 \approx 2.529 \cdot \frac{\Delta f}{fr} \dots\dots\dots (14)$$

② Lengthwise Vibration of Rectangular Plate Transducer

$$\frac{k_{31}^2}{1 - k_{31}^2} = -\frac{\pi}{2} \cdot \frac{fa}{fr} \cot \left(\frac{\pi}{2} \cdot \frac{fa}{fr} \right) \dots\dots\dots (15)$$

③ Longitudinal Vibration of Cylinder Transducer

$$k_{33}^2 = \frac{\pi}{2} \cdot \frac{fr}{fa} \cot \left(\frac{\pi}{2} \cdot \frac{fr}{fa} \right) \dots\dots\dots (16)$$

④ Vibration Along Thickness of Disk Transducer

$$k_t^2 = \frac{\pi}{2} \cdot \frac{fr}{fa} \cot \left(\frac{\pi}{2} \cdot \frac{fr}{fa} \right) \dots\dots\dots (17)$$

⑤ Shear Vibration of Rectangular Plate Transducer

$$k_{15}^2 = \frac{\pi}{2} \cdot \frac{fr}{fa} \cot \left(\frac{\pi}{2} \cdot \frac{fr}{fa} \right) \dots\dots\dots (18)$$

4 Mechanical Qm

Mechanical Qm gives the "steepness" of resonance of a mechanical vibration at and around the resonant frequency. It is given by the following equation :

$$Qm = \frac{1}{2 \pi fr R_1 C_f} = \frac{1}{2 \pi fr R_1 C_f \left\{ 1 - \left(\frac{fr}{fa} \right)^2 \right\}} \dots\dots\dots (19)$$

where R_1 : Resonant resistance

C_f : Free capacitance across electrodes

Characteristics of Piezoelectric Ceramics (PIEZOTITE®) 2

5 Young's Modulus Y^E

When stress T is applied to an elastic body within the proportional elastic range, strain S is given by the following formula :

$$S = s^E T$$

s^E is an elasticity constant (compliance), and Young's modulus is given as the inverse of compliance. For lengthwise vibrations shown in Fig. 3, for example, the Young's modulus is given by the following equation :

$$Y_{11}^E = (2\ell ft)^2 \cdot \rho = v^2 \cdot \rho \text{ (N/ m}^2\text{)} \dots\dots\dots (20)$$

where ρ : Density (kg/m³)
 v : Sound velocity (m/s)

6 Poisson's Ratio σ^E

When a constant stress is applied to an elastic body within its proportional elastic range, Poisson's ratio is defined as follows :

$$\sigma^E = \frac{\text{Distortion Rate Orthogonal to Stress}}{\text{Distortion Rate along Stress}}$$

7 Density ρ

Density can be determined from the volume and mass of any piezoelectric ceramic as follows :

$$\rho = \frac{m}{V} \text{ (kg / m}^3\text{)} \dots\dots\dots (21)$$

where m : Mass (kg)
 V : Volume (m³)

8 Relative Dielectric Constant $\frac{\epsilon^T}{\epsilon_0}$

Dielectric constant is an electrical displacement which results when a unity electric field is applied under no stress. It is given by the following formula :

$$D = \epsilon^T \cdot E$$

where E : Field strength
 D : Electrical displacement
 ϵ^T : Dielectric constant

Dielectric constant ϵ^T divided by the dielectric constant in a vacuum ϵ_0 (=8.854×10⁻¹²F/m) is called the relative dielectric constant. For the lengthwise vibration mode shown in Fig. 2, if the free capacitance across the electrodes at 1 kHz is assumed to be C_f , the relative dielectric constant for an electric field in the same direction of polarization is given by the equation :

$$\frac{\epsilon_{33}^T}{\epsilon_0} = \frac{C_f \cdot t}{\ell \cdot a \cdot \epsilon_0} \dots\dots\dots (22)$$

For the vibration along thickness shown in Fig. 2, if the free capacitance across the electrodes at 1 kHz is assumed to be C_f , the relative dielectric constant for an electric field orthogonal to the direction of polarization is given by this equation :

$$\frac{\epsilon_{11}^T}{\epsilon_0} = \frac{C_f \cdot t}{\ell \cdot a \cdot \epsilon_0} \dots\dots\dots (23)$$

9 Curie Temperature T_c

Curie temperature refers to the critical temperature at which crystals in the piezoelectric ceramic lose their spontaneous polarization and hence their piezoelectric property. It is defined as the temperature at which the dielectric constant is maximized when the temperature is increased.

10 Coercive Field E_c

Ferroelectric materials have a domain structure, as shown in Fig. 1. The dipole moment in each domain is oriented in the same direction and causes spontaneous polarization. If a varying electric field E is applied to it, the overall variation of polarization draws a hysteresis loop, as shown in Fig. 6. Once the material has an electric field applied to it, it does not return to the original domain structure when the electric field is removed, resulting in remanent polarization P_r . To cancel P_r , a certain strength of reverse electric field must be applied. The field strength E_c required to cancel the remanent polarization is called a coercive field.

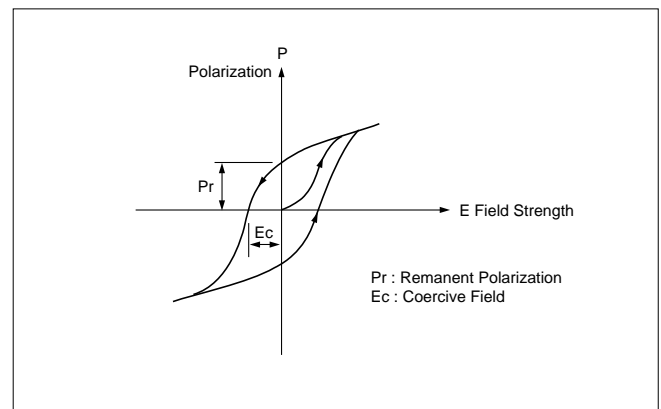


Fig. 6 Hysteresis Curve of a Ferroelectric Material

3

Murata's Piezoelectric Ceramics (PIEZOTITE[®]) Materials

1. Characteristics of Typical Materials

Table 1 shows the characteristics of typical Murata's piezoelectric ceramic materials.

| Item | Symbol (Unit) | P- 3 | P- 5C | P- 5E | P- 6C | P- 6E | P- 6F | P- 7 | P- 7B |
|------------------------------------|---|------------------------|--|-------|------------------|---------|-------|---|------------------------|
| Relative Dielectric Constant | $\epsilon_{11}^T/\epsilon_0$ | — | 1230 | 1490 | 760 | 1260 | 1670 | 1930 | 3200 |
| | $\epsilon_{33}^T/\epsilon_0$ | 1070 | 1550 | 1510 | 800 | 1380 | 1780 | 2100 | 4720 |
| Loss Coefficient | $\tan \delta$ (%) | 0.5 | 0.3 | 0.4 | 1.0 | 1.4 | 1.2 | 1.4 | 2.2 |
| Electro-mechanical Coupling Factor | k_p Radial (%) | 22 | 56 | 56 | 39 | 46 | 57 | 65 | 65 |
| | k_{31} Length (%) | 15 | 32 | 32 | 21 | 26 | 32 | 38 | 36 |
| | k_{33} Longitudinal (%) | 44 | 54 | 62 | 50 | 60 | 65 | 71 | 68 |
| | k_t Thickness (%) | 36 | 42 | 45 | 43 | 44 | 48 | 51 | 47 |
| | k_{15} Shear (%) | — | 50 | 60 | 47 | 53 | 61 | 66 | 57 |
| Piezoelectric Constant | d_{31} (10^{-12}m/V) | -44 | -131 | -131 | -3 | -94 | -148 | -207 | -303 |
| | d_{33} (10^{-12}m/V) | 133 | 225 | 271 | 135 | 235 | 311 | 410 | 603 |
| | d_{15} (10^{-12}m/V) | — | 294 | 400 | 196 | 309 | 431 | 550 | 592 |
| | g_{31} ($10^{-3}\text{V}\cdot\text{m/N}$) | -5 | -10 | -10 | -8 | -8 | -9 | -11 | -7 |
| | g_{33} ($10^{-3}\text{V}\cdot\text{m/N}$) | 14 | 16 | 20 | 19 | 19 | 20 | 22 | 14 |
| | g_{15} ($10^{-3}\text{V}\cdot\text{m/N}$) | — | 27 | 30 | 29 | 28 | 29 | 32 | 21 |
| Frequency Constant | N_p Radial (%) | 3140 | 1920 | 2250 | 2520 | 2410 | 2210 | 2050 | 1960 |
| | N_{31} Length (%) | 2270 | 1580 | 1610 | 1850 | 1730 | 1540 | 1430 | 1370 |
| | N_{33} Longitudinal (%) | 2210 | 1670 | 1550 | 1820 | 1670 | 1540 | 1400 | 1350 |
| | N_t Thickness (%) | 2590 | 2180 | 2060 | 2130 | 2110 | 2060 | 2000 | 1970 |
| | N_{15} Shear (%) | — | 1020 | 1010 | 1150 | 1080 | 1000 | 930 | 930 |
| Mechanical Q | Q_m | 720 | 2070 | 970 | 680 | 410 | 110 | 80 | 70 |
| Elastic constant | S_{11}^E ($10^{-12}\text{m}^2/\text{N}$) | 8.7 | 12.6 | 12.4 | 9.4 | 11.1 | 13.4 | 15.8 | 16.7 |
| | S_{12}^E ($10^{-12}\text{m}^2/\text{N}$) | -2.6 | -4.7 | -4.1 | -3.0 | -3.6 | -4.8 | -5.7 | -5.9 |
| | S_{13}^E ($10^{-12}\text{m}^2/\text{N}$) | -2.9 | -5.3 | -5.2 | -3.0 | -4.3 | -5.4 | -7.0 | -7.5 |
| | S_{33}^E ($10^{-12}\text{m}^2/\text{N}$) | 9.6 | 12.8 | 14.3 | 10.3 | 12.7 | 14.5 | 18.1 | 18.8 |
| | S_{44}^E ($10^{-12}\text{m}^2/\text{N}$) | — | 31.6 | 34.0 | 25.6 | 30.0 | 34.2 | 40.6 | 38.8 |
| | S_{66}^E ($10^{-12}\text{m}^2/\text{N}$) | 22.7 | 34.6 | 33.0 | 24.8 | 29.3 | 36.5 | 43.0 | 45.4 |
| | Y_{11}^E (10^{10}N/m^2) | 11.5 | 8.0 | 8.1 | 10.7 | 9.0 | 7.5 | 6.3 | 6.7 |
| Poisson's Ratio | σ^E | 0.30 | 0.37 | 0.33 | 0.32 | 0.33 | 0.36 | 0.36 | 0.36 |
| Density | ρ (10^3kg/m^3) | 5.6 | 8.0 | 7.8 | 7.7 | 7.6 | 7.9 | 7.8 | 8.0 |
| Temperature Coefficient | TK(fr) (ppm/°C) | — | 324 | 115 | 10 | 35 | 38 | 59 | 336 |
| | TK(Cf) (ppm/°C) | — | 1500 | 3500 | 2500 | 3000 | — | 4500 | 13500 |
| Curie Temperature | T_c (°C) | 120 | 360 | 280 | 320 | 270 | 280 | 300 | 180 |
| Linear Expansion Ratio | α ($10^{-6}/\text{°C}$) | 5 | 2 | 4 | 2 | 3 | 4 | 2 | 2 |
| Bending Strength | τ (10^6N/m^2) | 113 | 101 | 113 | 125 | 116 | 103 | 99 | 85 |
| Compressive Strength | K_{1c} ($10^6\text{N/m}^{1.5}$) | — | 0.7 | 1.1 | 1.3 | 1.2 | 0.9 | 0.8 | 0.9 |
| Applications | | Fish finders sonars | Ultrasonic cleaners Actuators for high power | | Knock sensors | Sensors | | Ultrasonic sensors Pickups Actuators Acoustic | Actuators Acoustics |

Note : This table shows typical values measured on standard test piece. Q_m , TK (fr) and TK (Cf) are measured for radial vibration mode.

Table 1 Characteristics of Murata's Typical Piezoelectric Ceramics (PIEZOTITE[®])

Murata's Piezoelectric Ceramics (PIEZOTITE®) Materials 3

2. Features of PIEZOTITE® Materials

Table 2 shows the features of PIEZOTITE® materials. Murata's piezoelectric ceramics include two types : barium titanate (BaTiO₃) and lead zirconate titanate

(PbTiO₃-PbZrO₃) Materials using lead zirconate titanate are available with different properties suitable for different applications.

| Type | Type Number | Features |
|-------------------------|-------------|--|
| Barium Titanate | P-3 | The major constituent of P-3 is barium titanate, with titanate additives to improve the characteristics at room temperature. While it has a lower electromechanical coupling coefficient and Curie temperature compared to Lead Zirconate Titanate, it is practical in underwater applications and has the advantage of economy. With these features, P-3 is best suited for use in fish finders or sonar. |
| Lead Zirconate Titanate | P-5E | Featuring a large electromechanical-coupling coefficient, mechanical Qm and minimal aging, P-5 is widely used for ultrasonic cleaners, high-power ultrasonic transducers, and other acoustic power applications. |
| | P-6C | Features superior temperature characteristics of resonant frequency and minimal aging. P-6 is often used in ceramic filters, ceramic resonators requiring high stability. |
| | P-7 | Features large electromechanical coupling coefficient, constant d and small mechanical Qm. P-7 has applications in piezoelectric buzzers, ultrasonic sensors, and other applications requiring non-resonance or broad bandwidth. |

Table 2 Features of Piezoelectric Ceramics

3. Temperature Characteristics and Aging

Fig. 7 shows examples of temperature characteristics of various materials.

Fig. 8 shows examples of aging characteristics of various materials. These examples show small aging characteristics.

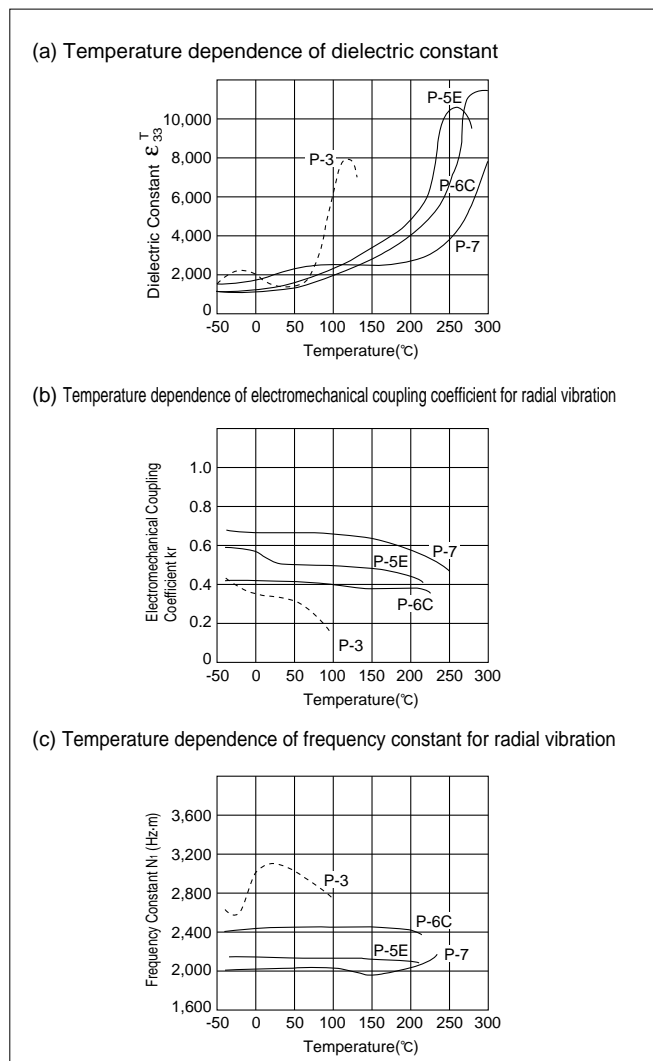


Fig. 7 Temperature Characteristics of Various Materials

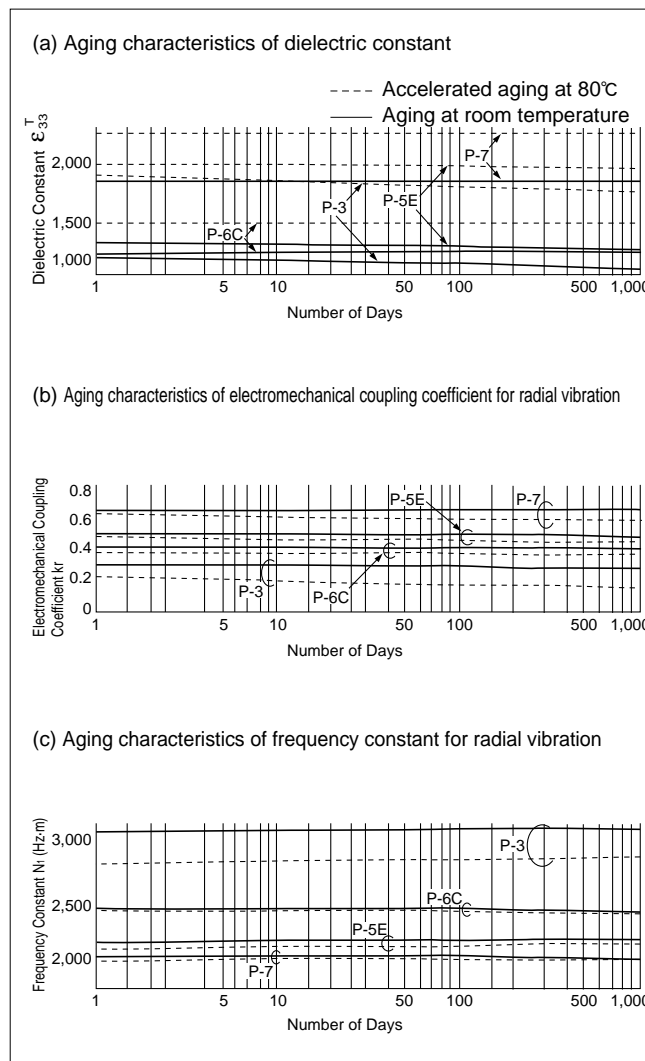
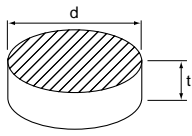
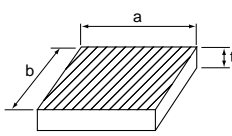
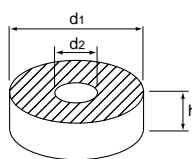


Fig. 8 Aging Characteristics of Various Materials

4 Murata's Piezoelectric Ceramics Resonators (PIEZOTITE®)

1. Shapes

PIEZOTITE® by Murata is available in various forms as shown in table 3.

| Shape | Diagram | Vibration Mode | Part Numbering (Ex.) |
|-------------------|---|---------------------|---|
| Disk |  | Radial Thickness | <div style="display: flex; justify-content: space-around;"> 7 D -15 -5400 </div> <div style="display: flex; justify-content: space-around; margin-top: 5px;"> ① ② ③ ④ </div> <p>① Indicates material P-7. ② Indicates disk cylinder. ③ Diameter d(mm) ④ Resonant frequency (thickness mode) (kHz)</p> |
| Rectangular Plate |  | Thickness Length | <div style="display: flex; justify-content: space-around;"> 7 R -34 -23 -6700 -1 </div> <div style="display: flex; justify-content: space-around; margin-top: 5px;"> ① ② ③ ④ ⑤ ⑥ </div> <p>① Indicates material P-7. ② Indicates rectangular plate or pillar. ③ Length a (mm) ④ Width b (mm) ⑤ Resonant frequency (thickness mode) (kHz) ⑥ Product ID</p> |
| Ring |  | Thickness | <div style="display: flex; justify-content: space-around;"> 6C C -10 -3R9 -1000 </div> <div style="display: flex; justify-content: space-around; margin-top: 5px;"> ① ② ③ ④ ⑤ </div> <p>① Indicates material P-6C. ② Indicates ring. ③ Outer diameter d1 (mm) ④ Inner diameter d2 (mm) ⑤ Resonant frequency (thickness mode) (kHz)</p> |

The capital letter "R" expresses significant digits.

Fig. 9 Shapes of Murata's Piezoelectric Ceramics PIEZOTITE®

2. Standard Specification Models

Table 3 shows standard specifications of PIEZOTITE® models.

| | Part Number | Dimensions (mm) | Resonant Frequency (kHz) | Coupling Coefficient (%) | Capacitance (pF) |
|--------------------|------------------------|------------------|--------------------------|--------------------------|------------------|
| Disks | 7D-10-9000-2 | ø10X0.2t | 200 (Radial mode) | 55 (kp) | 5200 |
| | 7D-15-5400 | ø15X0.4t | 137 (Radial mode) | 55 (kp) | 7200 |
| | 7D-25-1600 | ø25.5X1.27t | 80 (Radial mode) | 45 (kp) | 6300 |
| Rectangular Plates | 7R-34-23-2500 | 33.3LX22.8WX0.8t | 68 (Length mode) | 50 (kp) | 16000 |
| | 7R-34-23-4000-1 | 33.3LX22.8WX0.5t | 42 (Length mode) | 20 (kp) | 26000 |
| | 7R-34-23-6700 | 32.8LX22.3WX0.3t | 42 (Length mode) | 20 (kp) | 42000 |
| Rings | 6CC-21-15-700 | ø21.1Xø15X2.85t | 66 (Radial mode) | 18 (kp) | 450 |
| | 6CC-10-3R9-1000 | ø10Xø3.9X2.1t | 180 (Radial mode) | 20 (kp) | 230 |

Table 3 Standard Specifications of PIEZOTITE® Models

Murata's Piezoelectric Ceramics Resonators (PIEZOTITE®) **4**

3. Notice

Do not touch the component with bare hand because electrode may damaged.

5 Piezoelectric Ceramic (PIEZOTITE®) Applications

Piezoelectric ceramics transform electrical energy into mechanical energy and vice versa. Fig. 10 shows our PIEZOTITE® in applications which utilize this basic function of piezoelectric ceramics as an electrical-mechanical energy transducer.

In addition to the current line of products, Fig. 10 also lists some prototypes still under development (*1). Please

consult us concerning custom specifications and production of these new products. The application products are shown in , which are explained details in the following pages. For other products not shown in Fig. 10, please contact us. Items marked with an asterisk (*1) in Fig. 10 are available with individual catalogs and application manuals. For more details, refer to those related materials.

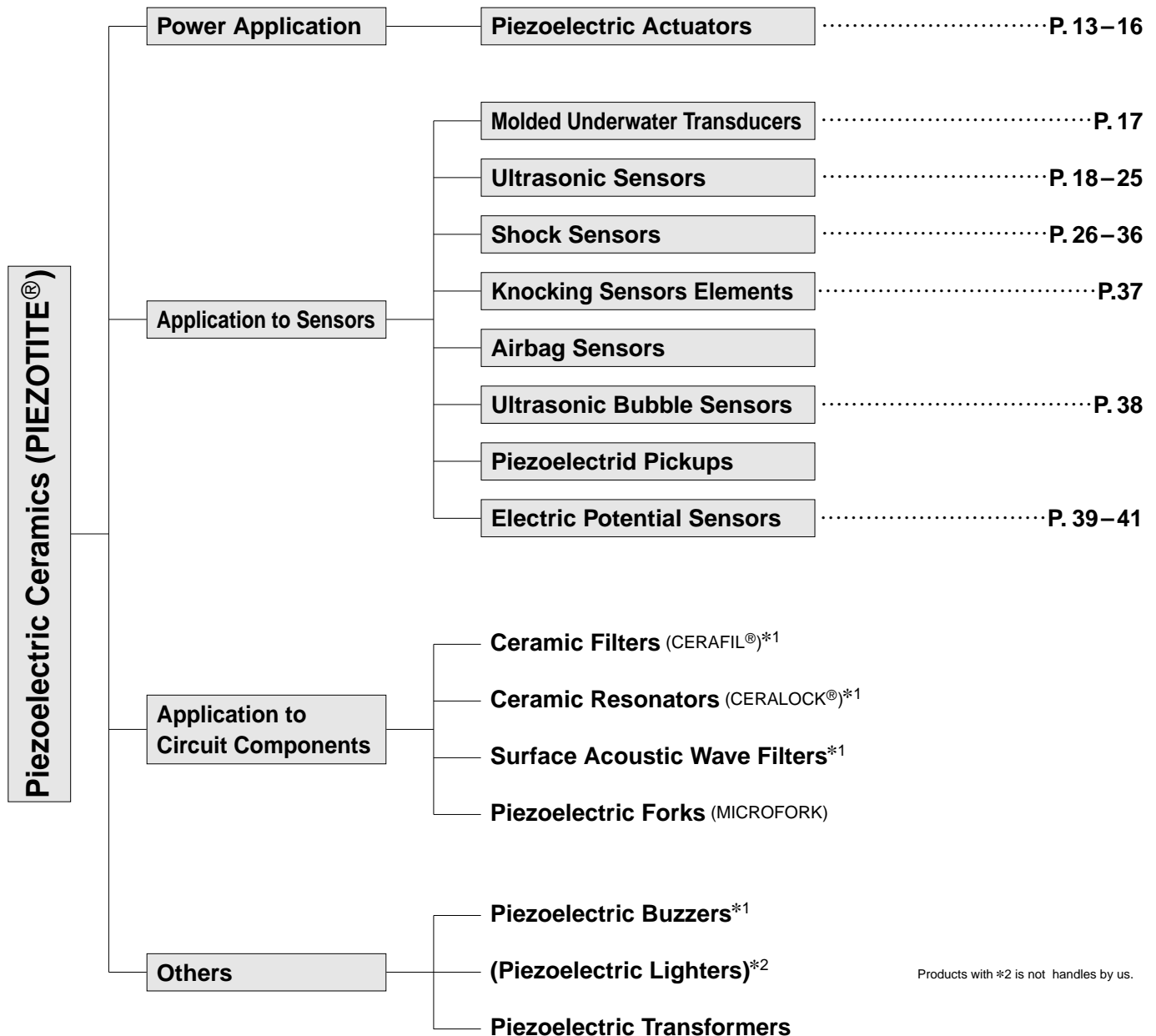


Fig. 10 Piezoelectric Ceramics (PIEZOTITE®) Applications

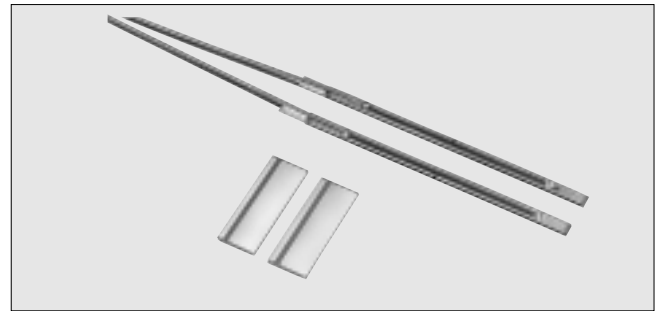
Piezoelectric Ceramic Sensors (PIEZOTITE®)



Piezoelectric Actuator

Exact displacement of 0.01μm to several hundreds μm can be obtained by controlling the applied voltage.

Piezoelectric actuators are used in the tracking adjustment of VCR heads, focus adjustment of VCR cameras, shutter drives of cameras, ink-jet printers and braille cells.



| Material | Piezoelectric Strain Constant | | Corrective Coefficient | Elastic Constant (corrected value) | | Coercive Field | Relative Dielectric Constant | Hysteresis |
|-------------|-------------------------------|-----------------------|------------------------|------------------------------------|-------------------------|----------------|------------------------------|------------|
| | $d_{31}(10^{-12}m/V)$ | $d_{33}(10^{-12}m/V)$ | | $M(10^{-16}m^2/V_2)$ | $Y_{11}E(10^{10}N/m^2)$ | | | |
| P-5E | 131 | 271 | 0.06 | 7.5 | 8.0 | 1500 | 1510 | 3 |
| P-7 | 207 | 410 | 1.08 | 5.5 | 5.5 | 800 | 2100 | 10 |
| P-7B | 303 | 603 | 3.89 | 5.0 | 5.5 | 500 | 4720 | 20 |

Hysteresis vary according to the applied voltage or shape (See Fig.2)

■ Notice

Please note that the component may be damaged if excess stress input voltage is applied. Please refer to the individual specification for the max. input voltage.

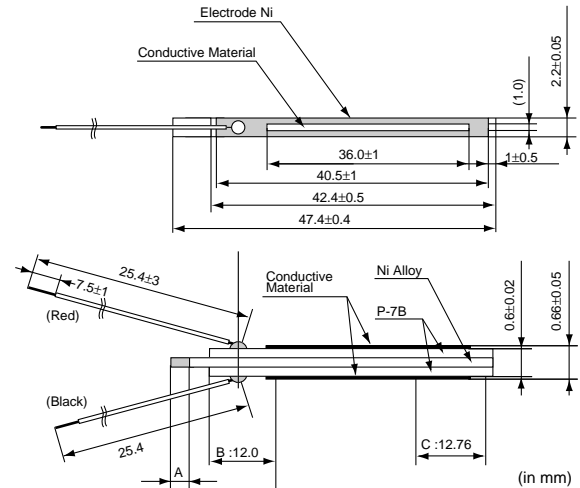
Bimorph Type Actuator

■ Features

1. Large displacement achieved with low voltage.
2. Compact, low-cost design.
3. High response speed.

■ Applications

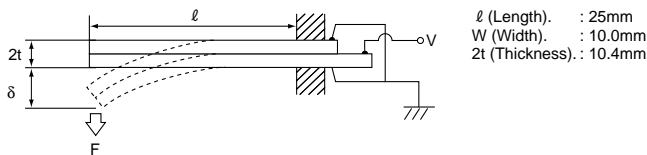
1. braille cells
2. shutter drives of cameras



* A : The length of pre-coating is more than 2.0mm from edge.
* There are protect-coating on the surface of ceramic.
Above dimensions don't include coating thickness.
The dimension included is as below,
Point B : 0.7mm
Point C : 0.74mm
* Lead wire : UL1571, AWG32

| Part Number | Deflection | Input Voltage (V) | Blocked Force (mN) | Capacitance (nF) |
|-------------|---|-------------------|---------------------------------|--|
| PKF02C5 | min. 1200 μm (1300 μm typ.) (at 200 V) | 200 V max. | 83.3 \pm 19.6mN (at 200 V) | 5.7 \pm 2.0nF (at 1 Vrms., 1 kHz) |

■ Construction



l (Length). : 25mm
 W (Width). : 10.0mm
 $2t$ (Thickness). : 10.4mm

Fig. 1

(Mechanical strength can be increased with metal plate.)

■ Characteristics (Construction in Fig.1)

1. Hysteresis

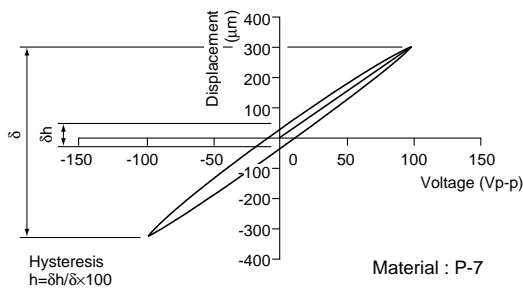


Fig. 2

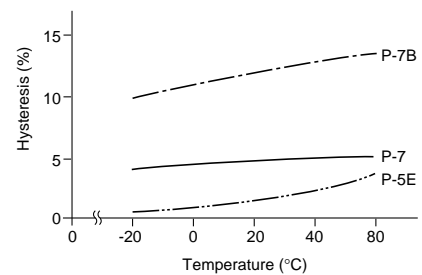
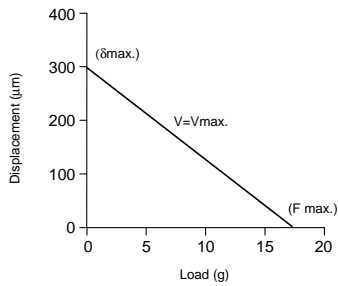


Fig.3

2. Displacement



Material : P-7
 Voltage : 100Vp-p
 Displacement : $\delta \approx 3 \cdot D_{31} \cdot V \cdot \left(\frac{R}{2t}\right)^2$
 Generated force : $F \approx \frac{3}{4} \cdot D_{31} \cdot V \cdot \left(\frac{2tW}{R}\right) \cdot Y_{11}$
 ($D_{31} = d_{31} + M \cdot V/2t$)
 (F : Load at 0 displacement)
 Maximum allowable voltage : $V_{max} \approx 0.7 \cdot E_c \cdot t$

Fig. 4

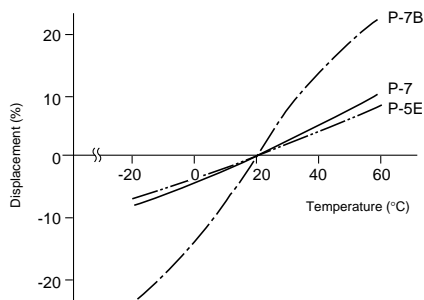


Fig.5

3. Material · shape-Displacement

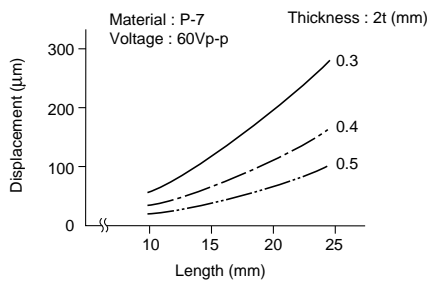


Fig.6

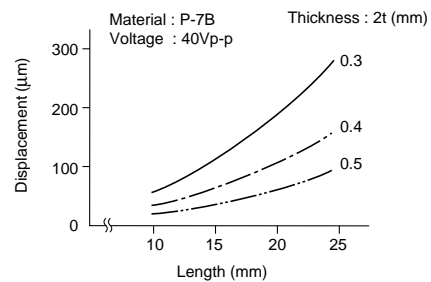


Fig.7

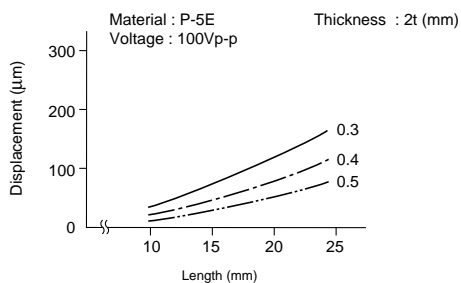


Fig.8

■ Notice

Please avoid applying an excessive stress to the transducer because it might be damaged.

Multilayer Type Actuator

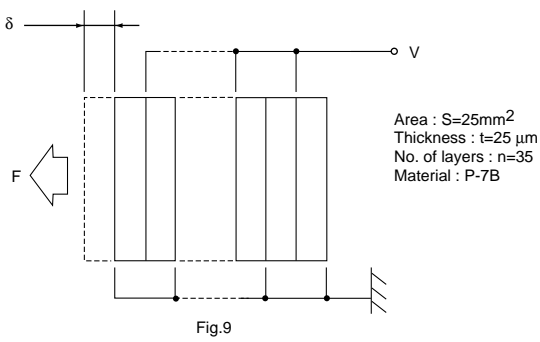
■ Features

1. Superior load-sustaining performance.
2. Precise micro-displacement.
3. High displacement response speed.

■ Applications

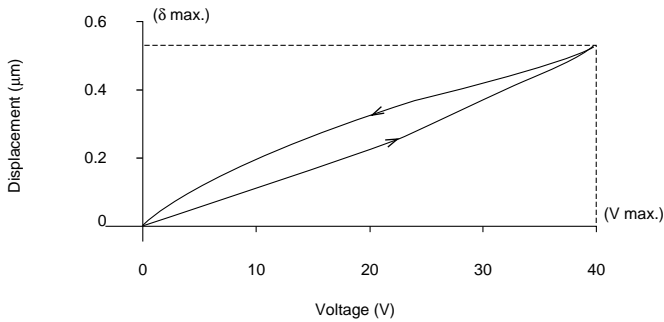
1. braille cells
2. shutter drives of cameras
3. Ink-jet Printer head
4. Location control for HDD MR-head

■ Construction

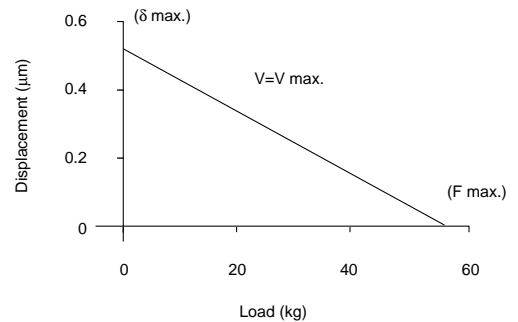


■ Characteristics

1. Hysteresis



2. Displacement



Piezoelectric Ceramic Sensors (PIEZOTITE®)



Molded Underwater Transducer

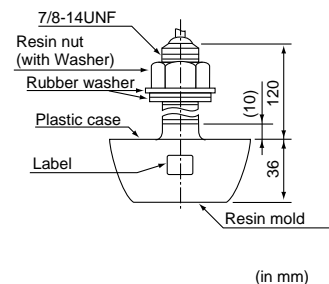
The molded underwater transducer is often used in fish finders and depth sounders. It emits an ultrasonic wave into the water so that the appropriate receiving device can detect the reflected wave in order to prove for fish or determine depth. Designed specifically for underwater use, this vibrator features not only high sensitivity but superior waterproof performance. The rugged design easily gives excellent performance even under high water pressure and waves.

■ Features

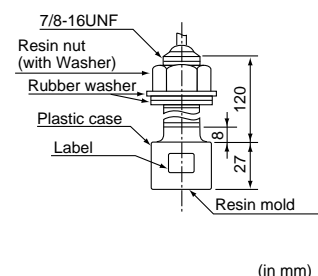
1. Unique mold technique using rubber, urethane, epoxy resin and other materials assures high sensitivity and dependability.
2. Many models are available for different driving frequencies, allowable input powers, and shapes.



LF type
(UT200LF8)



BA type
(UT200BA8)



| Part Number | Resonant Frequency (kHz) | Capacitance (pF) | Resonant Impedance (Ω) | Directivity (deg) | Allowable Input Power (W) |
|-------------|--------------------------|------------------|------------------------|-------------------|---------------------------|
| UT200BA8 | 200 | 1700 | 310 - 590 | 22 | 50 |
| UT200LF8 | 200 | 2700 | 230 - 430 | 12 | 200 |

Wire length is 8 m.

Directivity: The degree when sound pressure level is 6 dB down compared with the value at 0 degree.

Allowable input power : Denotes the instantaneous input power applied to Molded underwater transducer driven underwater.

The driving duty ratio is assumed to be 1/200 (the values in the table above are guidelines)

■ Notice

1. Pay close attention to directional characteristics when mounting.
2. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.
3. Do not use in the air.

Piezoelectric Ceramic Sensors (PIEZOTITE®)



Ultrasonic Sensors

Open Structure Type

■ Features

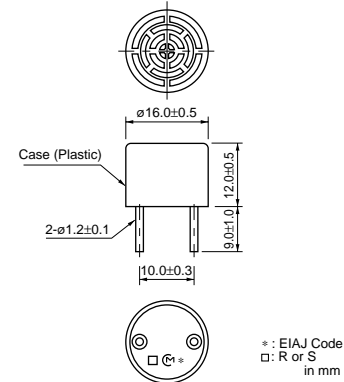
1. Compact and light weight.
2. High sensitivity and sound pressure.
3. Less power consumption.
4. High reliability.

■ Applications

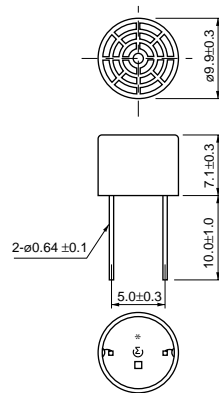
Burglar alarms, Range finders, Automatic doors, Remote control.



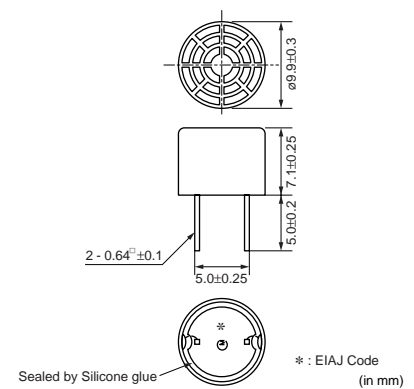
MA40B8R/S



MA40S4R/S



MA40S5



| Part Number | Construction | Using Method | Nominal Freq. (kHz) | Overall Sensitivity (mVp-p) | Sensitivity (dB) | S.P.L. (dB) | Directivity (°) | Cap. (pF) | Operating Temp. Range (°C) | Detectable Range (m) | Resolution (mm) | Max. Input Voltage (Vp-p) |
|-------------|--------------|--------------|---------------------|-----------------------------|--------------------------|---------------------------|-----------------|-----------|----------------------------|----------------------|-----------------|---|
| MA40B8R | Open struct. | Receiver | 40 | - | -63 typ. (0dB=10V/Pa) | - | 50 | 2000 | -30 to 85 | 0.2 to 6 | 9 | - |
| MA40B8S | Open struct. | Transmitter | 40 | - | - | 120 typ. (0dB=0.02mPa) | 50 | 2000 | -30 to 85 | 0.2 to 6 | 9 | 40 Continuous signal |
| MA40S4R | Open struct. | Receiver | 40 | - | -63 typ. (0dB=10V/Pa) | - | 80 | 2550 | -40 to 85 | 0.2 to 4 | 9 | - |
| MA40S4S | Open struct. | Transmitter | 40 | - | - | 120 typ. (0dB=0.02mPa) | 80 | 2550 | -40 to 85 | 0.2 to 4 | 9 | 20 Continuous signal |
| MA40S5 | Open struct. | Dual Use | 40 | 20 typ. | - | - | 60 typ. | 2550 | -30 to 85 | 0.5 to 2 | 9 | 20 Pulse width 0.4ms Interval 100ms |

Distance:30cm, Overall sensitivity:0dB=10Vp-p, Sensitivity:0dB=1Vrms/μbar, Sound pressure level:0dB=2x10⁻⁴μbar, 1μbar=0.1Pa

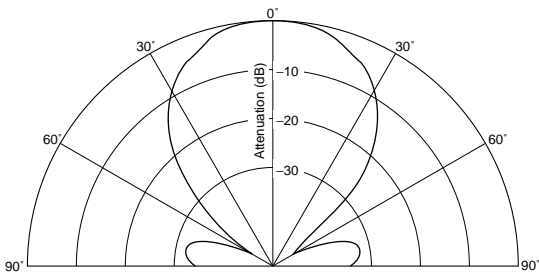
The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

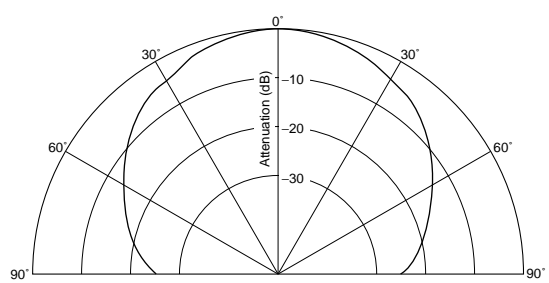
Directivity, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.

■ Directivity in Sensitivity

MA40B8R

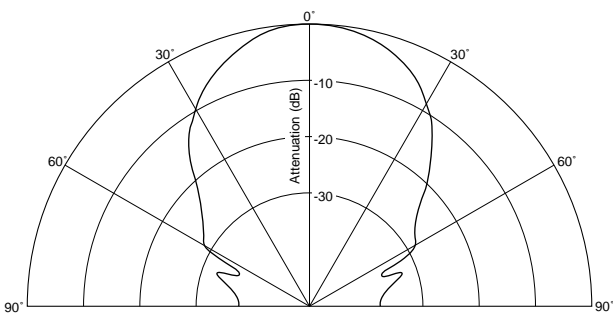


MA40S4R



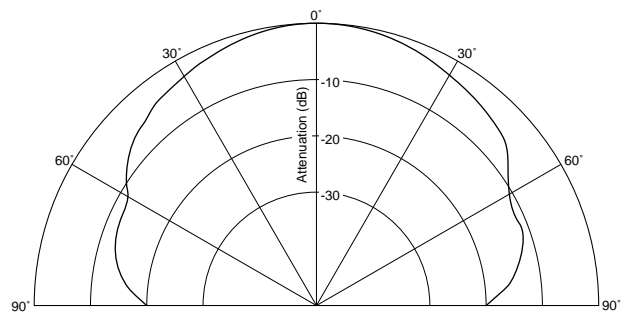
■ Directivity in S. P. L.

MA40B8S



■ Directivity in S. P. L.

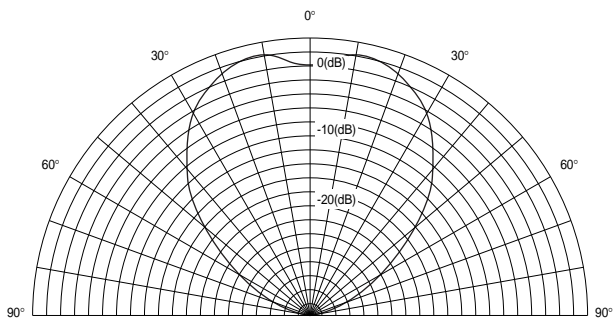
MA40S4S



■ Directivity in Overall Sensitivity

MA40S5

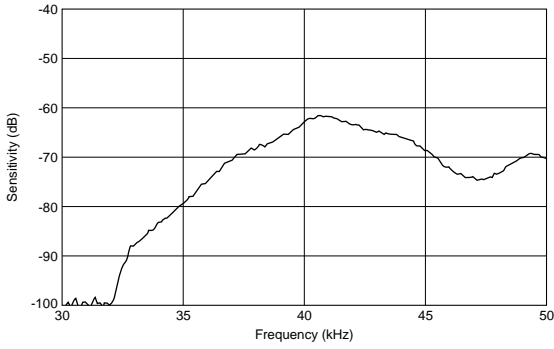
Beam Pattern



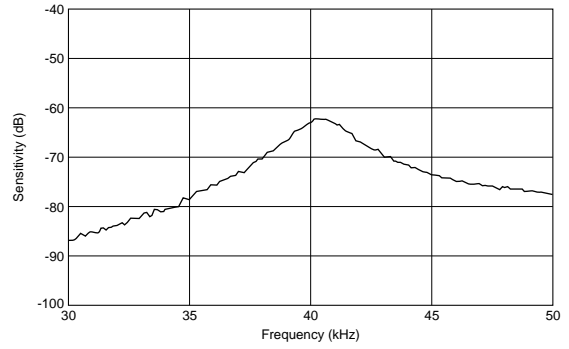
5

■ S. P. L. -Freq. Characteristics

MA40B8R

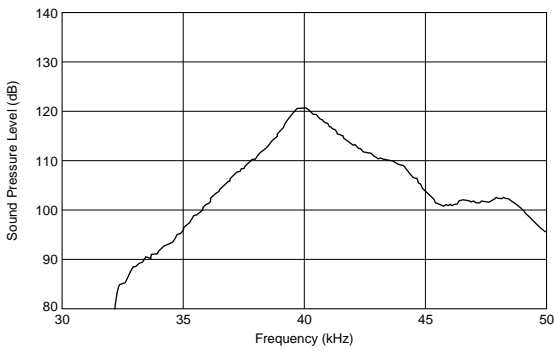


MA40S4R

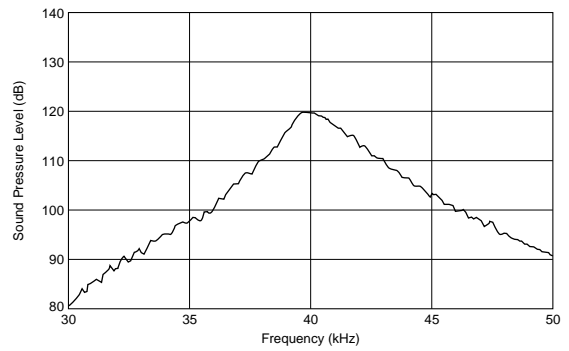


■ Sensitivity-Freq. Characteristics

MA40B8S



MA40S4S



5

Water Proof Type Symmetric Directivity

■ Features

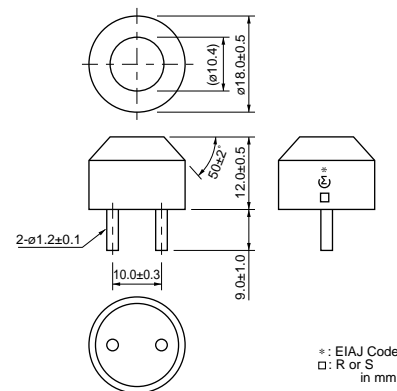
1. Compact and light weight.
2. High sensitivity and sound pressure.
3. Less power consumption.
4. High reliability.

■ Applications

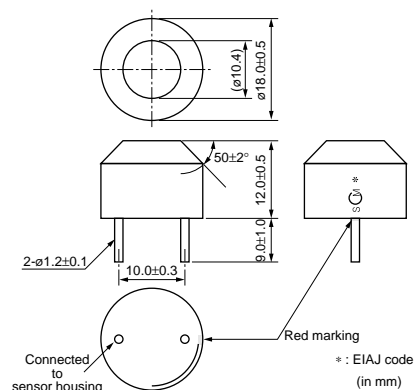
Back sonar of automobiles, Parking meters, Water level meters.



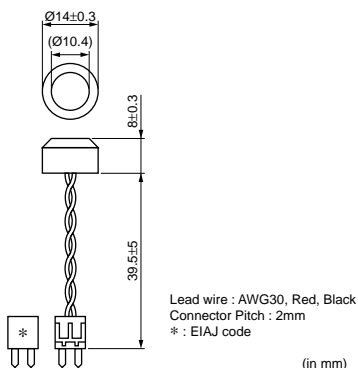
MA40E7R/S



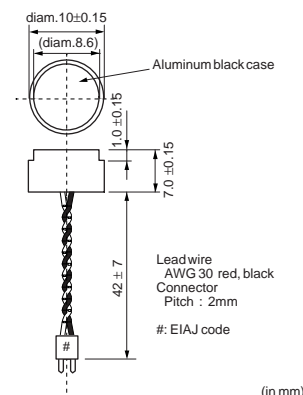
MA40E7S-1



MA40E8-2



MA40MC10-1B



| Part Number | Construction | Using Method | Nominal Freq. (kHz) | Overall Sensitivity | Sensitivity (dB) | S.P.L. (dB) | Directivity (°) | Cap. (pF) | Operating Temp. Range (°C) | Detectable Range (m) | Resolution (mm) | Max. Input Voltage (Vp-p) |
|-------------|--------------|--------------|---------------------|---------------------|--|---------------------------|-----------------|-----------|----------------------------|----------------------|-----------------|--|
| MA40E7R | Water proof | Receiver | 40 | - | -74 min. (0dB=10V/Pa) | - | 100 | 2200 | -30 to 85 | 0.2 to 3 | 9 | - |
| MA40E7S | Water proof | Transmitter | 40 | - | - | 106 min. (0dB=0.02mPa) | 100 | 2200 | -30 to 85 | 0.2 to 3 | 9 | 100 Pulse width 0.4ms Interval 100ms |
| MA40E7S-1 | Water proof | Dual Use | 40 | - | -72 min. (0dB=10V/Pa) : reference only | 106 min. (0dB=0.02mPa) | 75 | 2200 | -30 to 85 | 0.2 to 3 | 9 | 100 Pulse width 0.4ms Interval 100ms |
| MA40E8-2 | Water proof | Dual Use | 40 | - | -85 min. (0dB=10V/Pa) | 106 min. (0dB=0.02mPa) | 75 | 2800 | -30 to 85 | 0.2 to 1.5 | 9 | 160 Pulse width 0.8ms Interval 60ms |
| MA40MC10-1B | Water proof | Dual Use | 40 | - | -86 min. (0dB=10V/Pa) | 104 min. (0dB=0.02mPa) | 100 typ. | 2400 | -30 to 85 | 0.2 to 1.5 | 9 | 160 Pulse width 0.8ms Interval 60ms |

Distance:30cm, Overall sensitivity:0dB=10Vp-p, Sensitivity:0dB=1Vrms/μbar, Sound pressure level:0dB=2x10⁻⁴μbar, 1μbar=0.1Pa

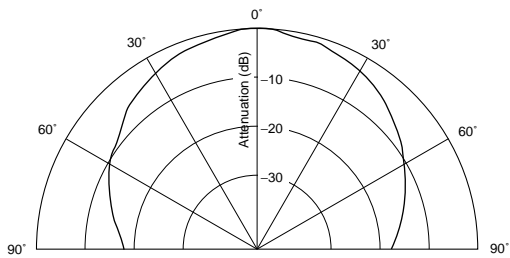
The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

Directivity, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.

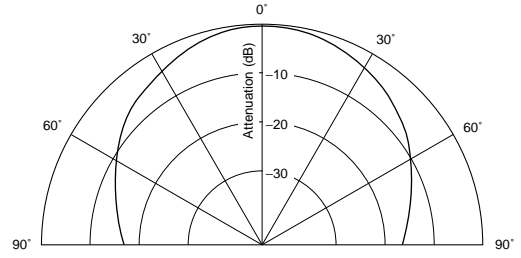
■ Directivity in Sensitivity

MA40E7R



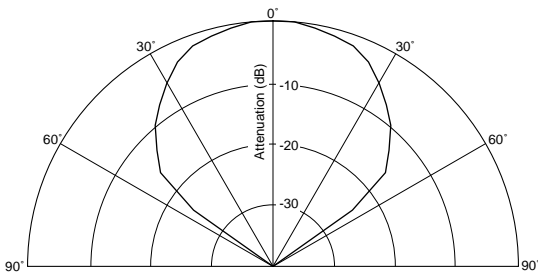
■ Directivity in S. P. L.

MA40E7S

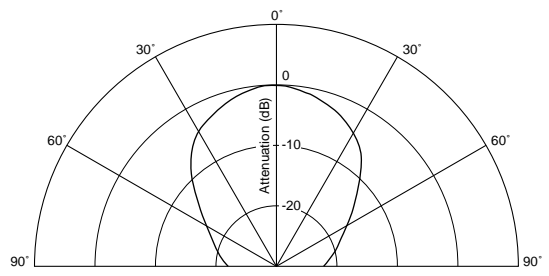


■ Directivity in Overall Sensitivity

MA40E7S-1

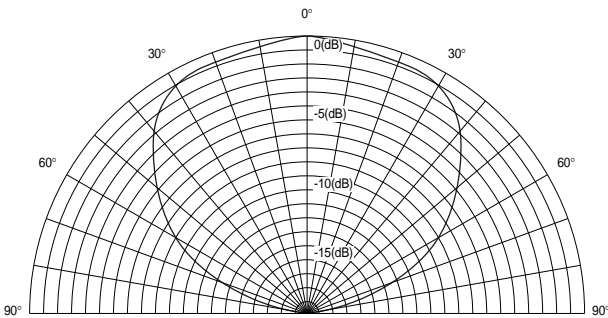


MA40E8-2



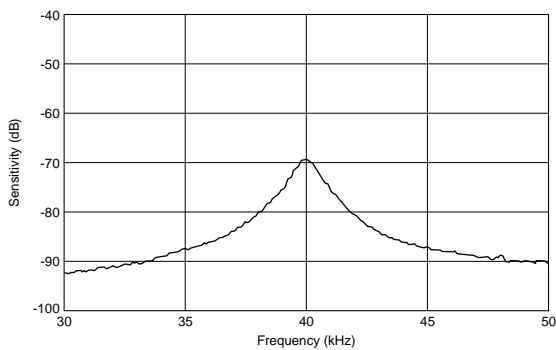
MA40MC10-1B

Beam Pattern



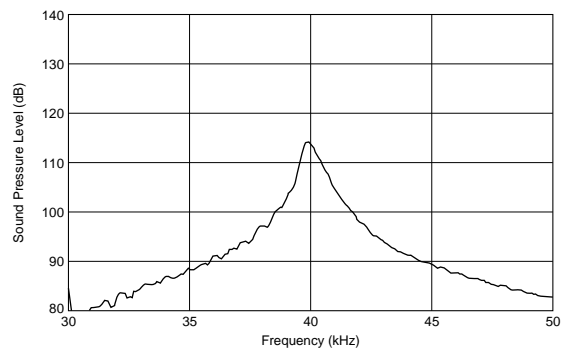
■ S. P. L. -Freq. Characteristics

MA40E7R



■ Sensitivity-Freq. Characteristics

MA40E7S



5

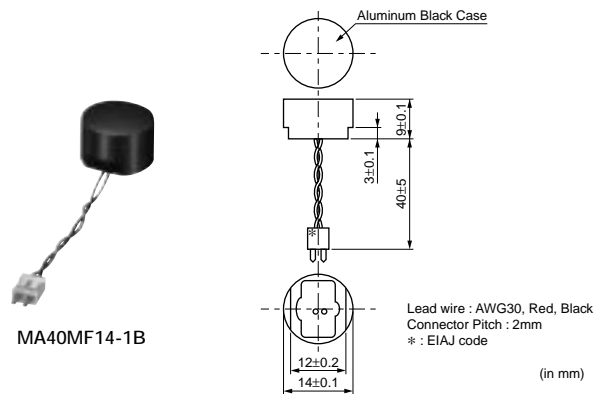
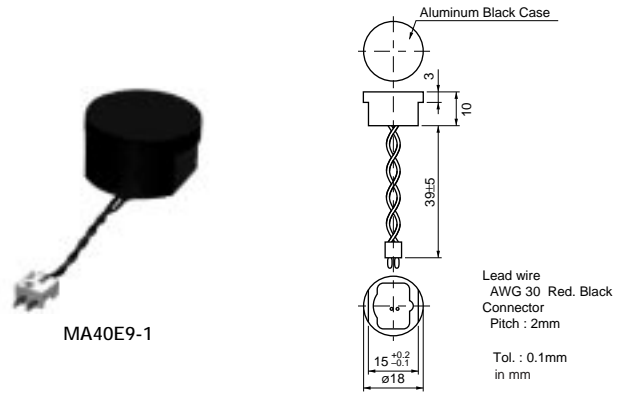
Water Proof Type Asymmetric Directivity

■ Features

1. Compact and light weight.
2. High sensitivity and sound pressure.
3. Less power consumption.
4. High reliability.
5. Compressed directivity by itself

■ Applications

Vack sonar of automobiles, Parking meters, Water level meter.



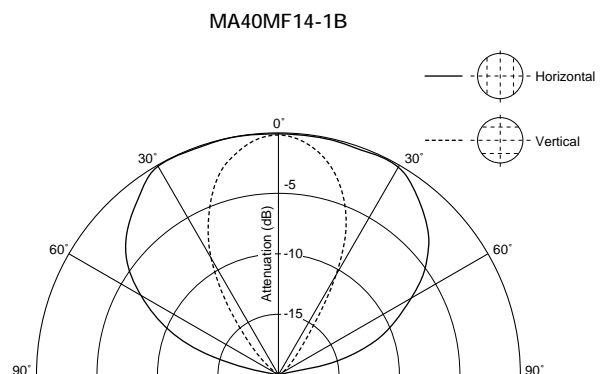
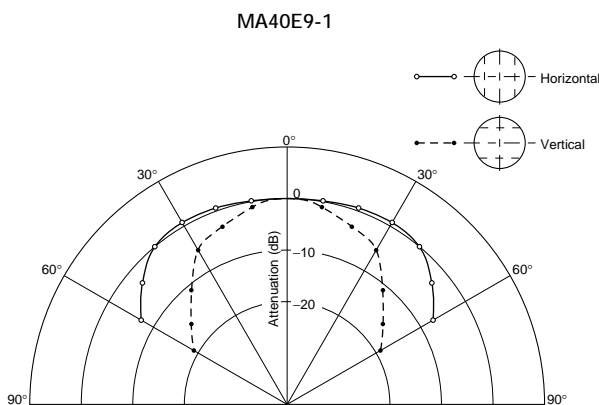
| Part Number | Construction | Using Method | Nominal Freq. (kHz) | Overall Sensitivity | Sensitivity (dB) | S.P.L. (dB) | Directivity (°) | Cap. (pF) | Operating Temp. Range (°C) | Detectable Range (m) | Resolution (mm) | Max. Input Voltage (Vp-p) |
|-------------|--------------|--------------|---------------------|---------------------|--------------------------|---------------------------|-----------------|-----------|----------------------------|----------------------|-----------------|---|
| MA40E9-1 | Water proof | Dual Use | 40 | - | -85 min. (0dB=10V/Pa) | 103 min. (0dB=0.02mPa) | 100 x50° | 4000 | -30 to 85 | 0.2 to 1.5 | 9 | 160 Pulse width 0.8ms Interval 60ms |
| MA40MF14-1B | Water proof | Dual Use | 40 | - | -87 min. (0dB=10V/Pa) | 103 min. (0dB=0.02mPa) | 110 x50° | 4400 | -30 to 85 | 0.2 to 1.5 | 9 | 160 Pulse width 0.8ms Interval 60ms |

The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

Directivity, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.

■ Directivity in Overall Sensitivity



High-frequency Type

■ Features

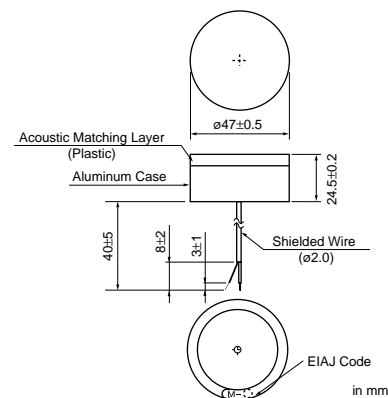
Using longitudinal vibration and matching with the air by acoustic matching layer, this type realized high sensitivity. Because of short wavelength, this type has sharp directivity and can be used high precise measurement.

■ Applications

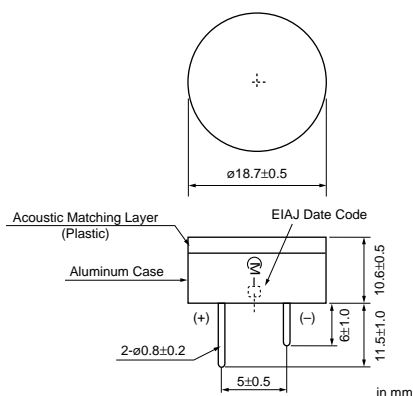
Approach switch for FA, Distance meter, Water or liquid level meters.



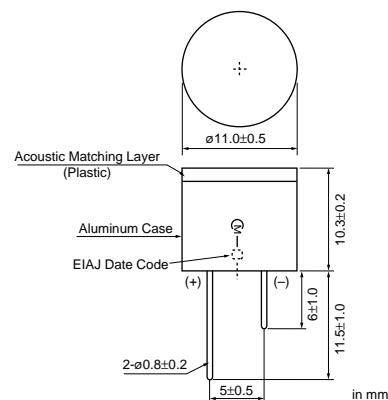
MA80A1



MA200A1



MA400A1



| Part Number | Construction | Using Method | Nominal Freq. (kHz) | Overall Sensitivity (dB) | Sensitivity | S.P.L. | Directivity (°) | Cap. | Operating Temp. Range (°C) | Detectable Range (m) | Resolution (mm) | Max. Input Voltage (Vp-p) |
|-------------|---------------------|--------------|---------------------|------------------------------------|-------------|--------|-----------------|------|----------------------------|----------------------|-----------------|---|
| MA80A1 | High frequency type | Dual Use | 75 +/-5 | -47 min. 0dB=18Vpp (at 50cm) | - | - | 7 | - | -10 to 60 | 0.5 to 5 | 4 | 120 Pulse width 0.6ms Interval 50ms |
| MA200A1 | High frequency type | Dual Use | 200 +/-10 | -54 min. 0dB=18Vpp (at 20cm) | - | - | 7 | - | -30 to 60 | 0.2 to 1 | 2 | 120 Pulse width 250µs Interval 20ms |
| MA400A1 | High frequency type | Dual Use | 400 +/-20 | -74 min. 0dB=18Vpp (at 10cm) | - | - | 7 | - | -30 to 60 | 0.06 to 0.3 | 1 | 120 Pulse width 125µs Interval 10ms |

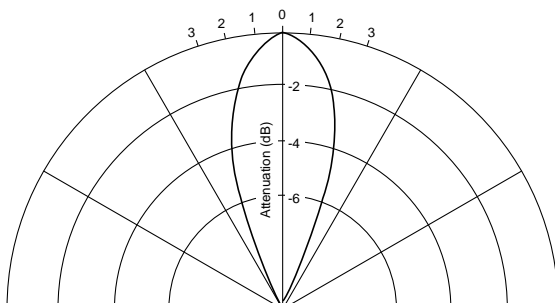
The sensor can be used in the operating temperature range.

Please refer to the individual specification for the temperature drift of Sensitivity/Sound pressure level or environmental characteristics in that temperature range.

Directivity, detectable range and resolution are typical values. They can be changed by application circuit and fixing method of the sensor.

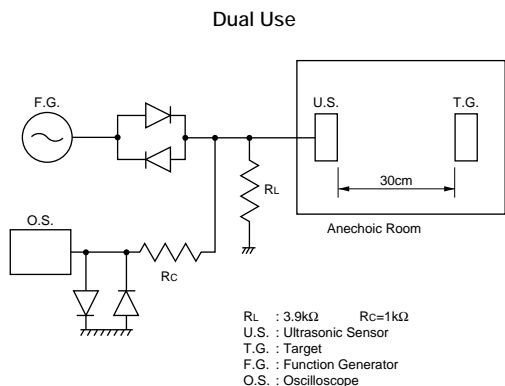
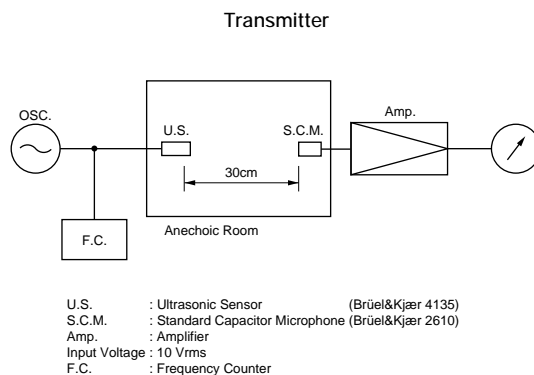
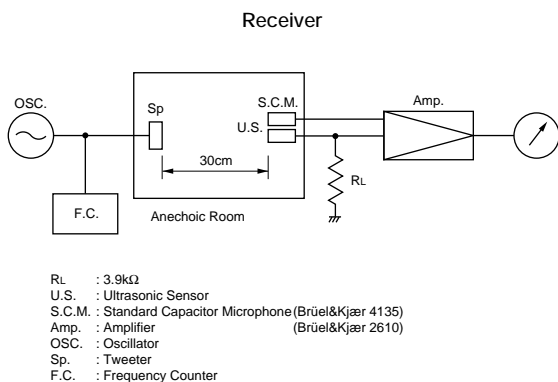
■ Directivity in Overall Sensitivity

MA_A1 Series



Data/Notice/Part Numbering

■ Test Circuit



■ Notice (Soldering and Mounting)

1. Pay attention to the mounting position as these sensors have directivity.
2. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.
3. Do not use in water.

● Part Numbering (The structure of the "Global Part Numbers" that have been adopted since June 2001 and the meaning of each code are described herein.) (If you have any questions about details, inquire at your usual Murata sales office or distributor.)

Ultrasonic Sensors

(Global Part Number) **MA** **40MF** **14** **-1N** **-M**

① ② ③ ④ ⑤

- ① Product ID
- ② Series
- ③ Characteristics
- ④ Individual Specification Code
- ⑤ Packaging

* Global Part Number shows only an example which might be different from actual part number.

* Any other definitions than "① Product ID" might have different digit numbers from actual Global Part Number.

Piezoelectric Ceramic Sensors (PIEZOTITE®)



Shock Sensors

The shock sensor, PKGS series, is acceleration sensor with 2 terminals and detects acceleration & shock to be applied from outside, as electrical signal.

By bimorph piezo elements clamped at the two-end with original polarization technology, the shock sensor has high sensitivity and excellent durability.

The shock sensor is reflow solderable SMD type.

The shock sensor can have inclined primary axis so that appropriate shock sensor can be chosen for shock detection in HDD (Hard Disk Drive) and optical pick-up control in optical drive & optical-magnetic Drive.



■ Features

1. Small size, low profile, high sensitivity and excellent durability.
2. Excellent linearity.
3. High resonance frequency and wide bandwidth.
4. Available tape and reel packaging.
5. Reflowable.
6. In addition to the voltage sensitivity type shock sensor (ME, LB and LC series), new type, the electrical charge sensitivity type shock sensor (NB, MF and LD series) are released. NB, MF and LD series have better anti-reflow temperature.

■ Applications

1. HDD data writing protection, while shock is applied from outside.
2. Shock detection and protection in DVD, CD-R, CD-RW etc.
3. Pick-up control for disk type storage in Digital camera, Camcorder etc.
4. Other applications requiring acceleration detection.

■ Primary Axis Inclined Angle

The acceleration detection direction with the shock sensor can be inclined relative to the PCB. This inclination is called the primary-axis-inclined angle and can be selected from the four variations that are shown in the diagram on the right-0, 25, 45, and 90 degrees, respectively.

The acceleration detection sensitivity is greatest with the acceleration in the primary axis direction (direction D). With the 25- and 45-degree sensor types,

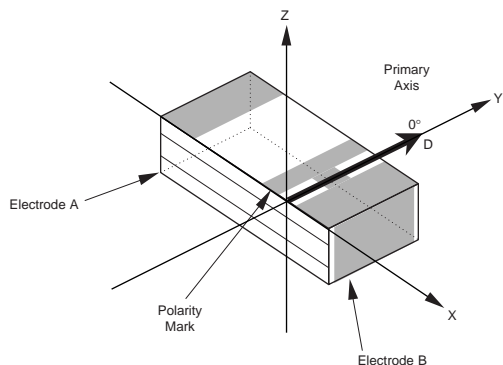
the detection sensitivity is available in both the Y and Z directions.

■ Polarity

The shock sensor has polarity. Referring to the diagram on the right, when acceleration is applied in direction D, a positive voltage (relative to the voltage on electrode A) occurs on electrode B.

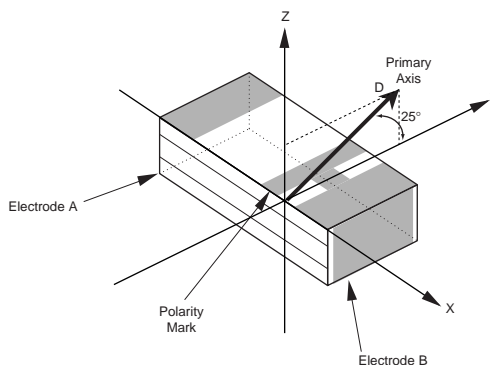
■ Primary Axis Inclined Angle (0 degree)

PKGS-00_-R



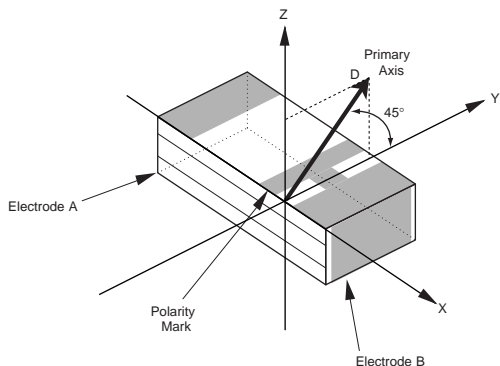
■ Primary Axis Inclined Angle (25 degree)

PKGS-25_-R



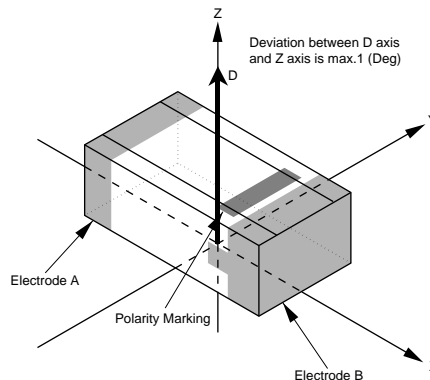
■ Primary Axis Inclined Angle (45 degree)

PKGS-45_-R



■ Primary Axis Inclined Angle (90 degree)

PKGS-90LC-R



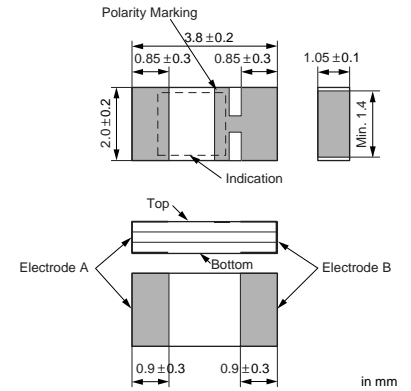
Under bar shown in part number is filled with two letters of Characteristics codes.

5

Charge Sensitivity Type PKGS-_NB-R



PKGS-_NB-R



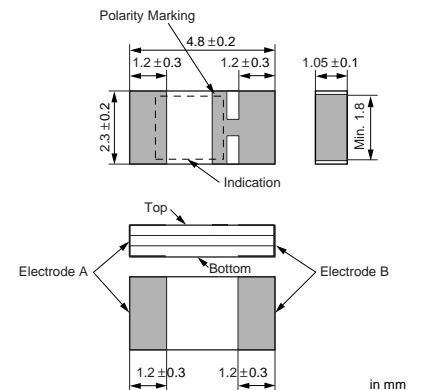
| Part Number | Primary Axis Inclined Angle (°) | Sensitivity* (pC/G) | Capacitance (pF) | Insulation Resistance (M ohm) | Resonant Frequency (kHz) | Non-linearity (%) |
|-------------|---------------------------------|---------------------|------------------|-------------------------------|--------------------------|-------------------|
| PKGS-00NB-R | 0 | 0.153 typ. | 480 typ. | 500 min. | 44 typ. | 1 typ. |
| PKGS-25NB-R | 25 | 0.168 typ. | 520 typ. | 500 min. | 44 typ. | 1 typ. |
| PKGS-45NB-R | 45 | 0.133 typ. | 440 typ. | 500 min. | 43 typ. | 1 typ. |

Operatig Temperature Range : -40°C to 85°C Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

Charge Sensitivity Large Type PKGS-_MF-R Series



PKGS-_MF-R



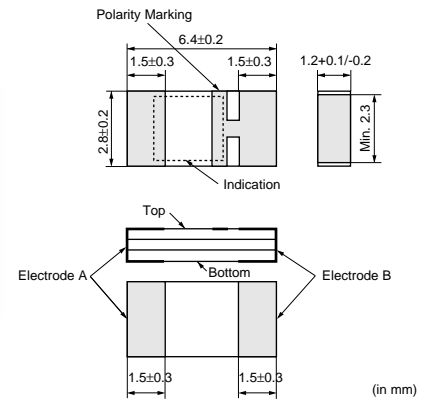
| Part Number | Primary Axis Inclined Angle (°) | Sensitivity* (pC/G) | Capacitance (pF) | Insulation Resistance (M ohm) | Resonant Frequency (kHz) | Non-linearity (%) |
|-------------|---------------------------------|---------------------|------------------|-------------------------------|--------------------------|-------------------|
| PKGS-00MF-R | 0 | 0.325 typ. | 570 typ. | 500 min. | 27 typ. | 1 typ. |
| PKGS-25MF-R | 25 | 0.350 typ. | 610 typ. | 500 min. | 27 typ. | 1 typ. |
| PKGS-45MF-R | 45 | 0.285 typ. | 490 typ. | 500 min. | 26 typ. | 1 typ. |

Operatig Temperature Range : -40°C to 85°C Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

Charge Sensitivity Type PKGS-LD-R Series



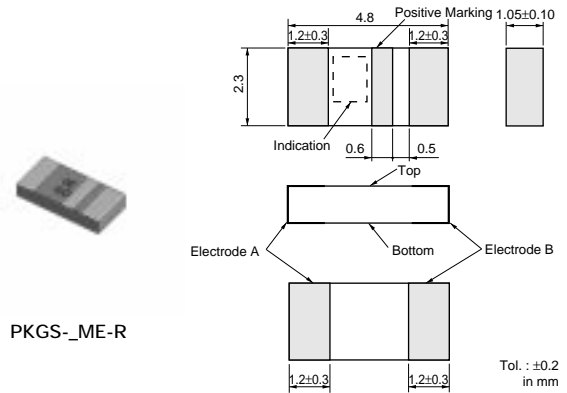
PKGS-LD-R



| Part Number | Primary Axis Inclined Angle (°) | Sensitivity* (pC/G) | Capacitance (pF) | Insulation Resistance (M ohm) | Resonant Frequency (kHz) | Non-linearity (%) |
|--------------------|---------------------------------|---------------------|------------------|-------------------------------|--------------------------|-------------------|
| PKGS-00LD-R | 0 | 0.840 typ. | 770 typ. | 500 min. | 20 typ. | 1 typ. |
| PKGS-45LD-R | 45 | 0.790 typ. | 690 typ. | 500 min. | 18 typ. | 1 typ. |

Operatig Temperature Range : -40°C to 85°C Storage Temperature Range : -40°C to 85°C
 *1G=9.80665m/s²

Voltage sensitivity Type PKGS-ME-R Series

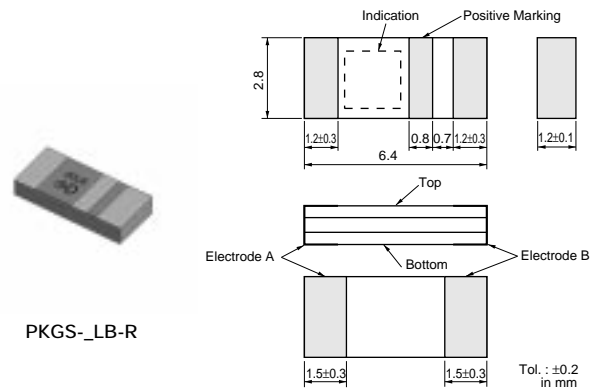


PKGS-ME-R

| Part Number | Primary Axis Inclined Angle (°) | Sensitivity* (mV/G) | Capacitance (pF) | Insulation Resistance (M ohm) | Resonant Frequency (kHz) | Non-linearity (%) |
|-------------|---------------------------------|---------------------|------------------|-------------------------------|--------------------------|-------------------|
| PKGS-00ME-R | 0 | 1.00 typ. | 160 typ. | 500 min. | 27 typ. | 1 typ. |
| PKGS-25ME-R | 25 | 1.0 typ. | 170 typ. | 500 min. | 27 typ. | 1 typ. |
| PKGS-45ME-R | 45 | 1.00 typ. | 210 typ. | 500 min. | 27 typ. | 1 typ. |

Operatig Temperature Range : -40°C to 85°C Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

Voltage sensitivity Type PKGS-LB-R Series



PKGS-LB-R

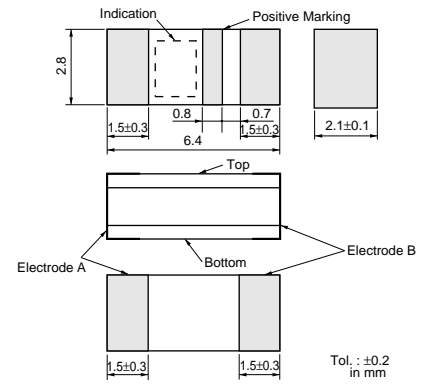
| Part Number | Primary Axis Inclined Angle (°) | Sensitivity* (mV/G) | Capacitance (pF) | Insulation Resistance (M ohm) | Resonant Frequency (kHz) | Non-linearity (%) |
|-------------|---------------------------------|---------------------|------------------|-------------------------------|--------------------------|-------------------|
| PKGS-00LB-R | 0 | 1.85 typ. | 210 typ. | 500 min. | 20 typ. | 1 typ. |
| PKGS-25LB-R | 25 | 1.85 typ. | 240 typ. | 500 min. | 20 typ. | 1 typ. |
| PKGS-45LB-R | 45 | 1.93 typ. | 295 typ. | 500 min. | 20 typ. | 1 typ. |

Operatig Temperature Range : -40°C to 85°C Storage Temperature Range : -40°C to 85°C
*1G=9.80665m/s²

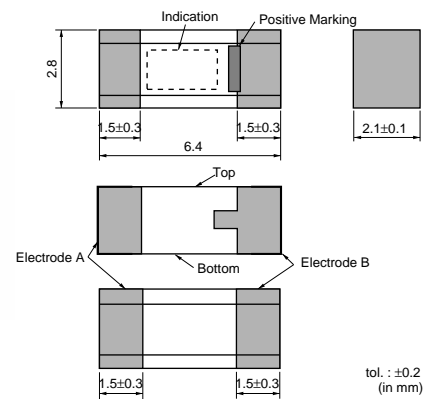
Voltage sensitivity Type PKGS-LC-R Series



PKGS-00LC-R



PKGS-90LC-R



| Part Number | Primary Axis Inclined Angle (°) | Sensitivity* (mV/G) | Capacitance (pF) | Insulation Resistance (M ohm) | Resonant Frequency (kHz) | Non-linearity (%) |
|-------------|---------------------------------|---------------------|------------------|-------------------------------|--------------------------|-------------------|
| PKGS-00LC-R | 0 | 2.10 typ. | 420 typ. | 500 min. | 20 typ. | 1 typ. |
| PKGS-90LC-R | 90 | 2.10 typ. | 420 typ. | 500 min. | 20 typ. | 1 typ. |

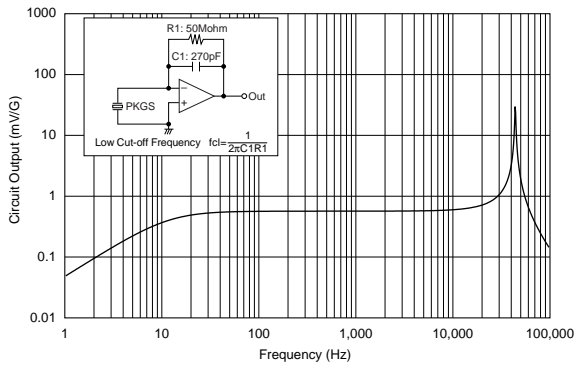
Operatig Temperature Range : -40°C to 85°C Storage Temperature Range : -40°C to 85°C
 *1G=9.80665m/s²

5

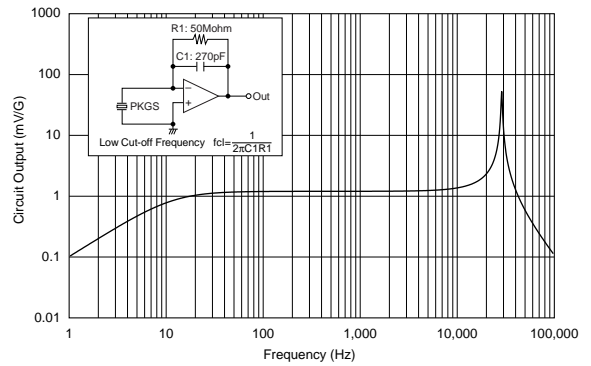
Reference Data

■ Freq. Characteristics (Typical)

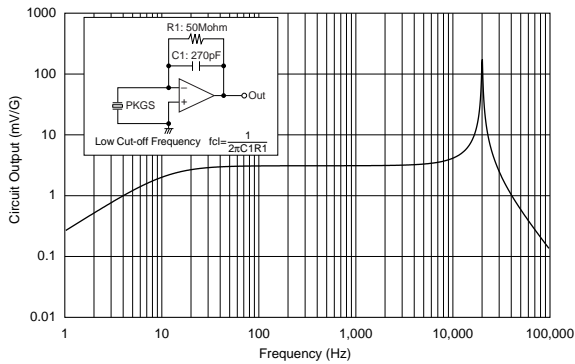
PKGS-_NB-R



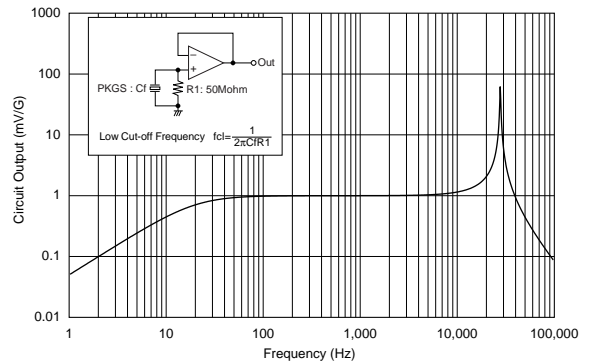
PKGS-_MF-R



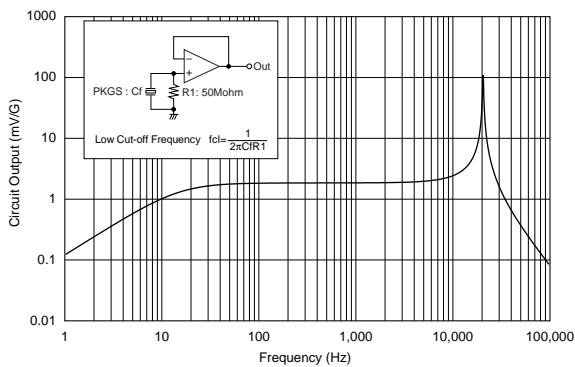
PKGS-_LD-R



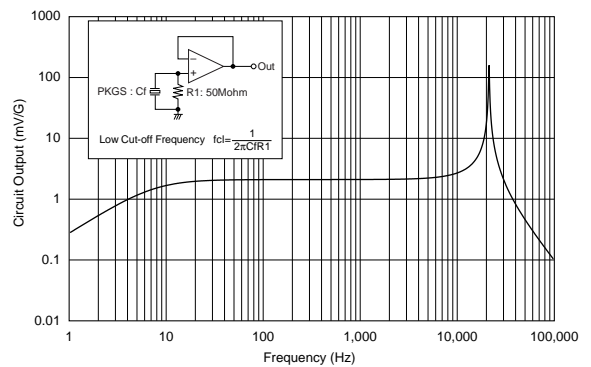
PKGS-_ME-R



PKGS-_LB-R



PKGS-_LC-R

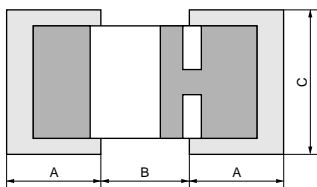


Under bar shown in part number is filled with two figures of inclined angle.

PKGS Series Mounting/Notice/Part Numbering

Standard Land Pattern

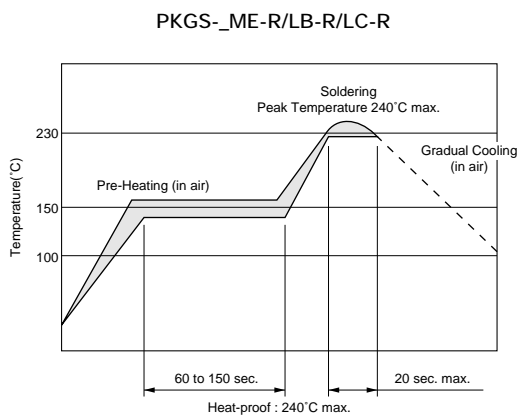
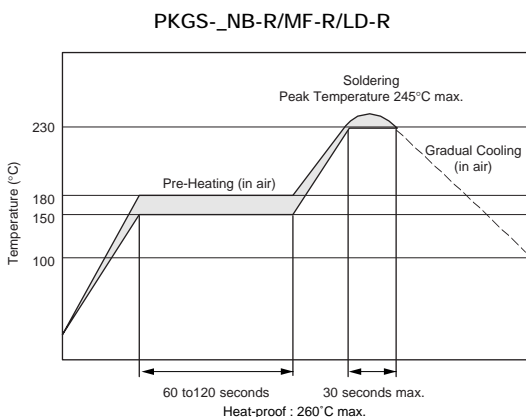
Standard Land Pattern



Dimensions

| | PKGS-□□NB-R | PKGS-□□MF-R/ME-R | PKGS-□□LD-R/LB-R/LC-R |
|---|-------------|------------------|-----------------------|
| A | 1.4 mm | 1.7 mm | 2.0 mm |
| B | 2.0 mm | 2.4 mm | 3.4 mm |
| C | 2.0 mm | 2.3 mm | 2.8 mm |

Standard Reflow Profile



Notice (Rating)

Please do not apply DC voltage for this shock sensor.

Notice (Soldering and Mounting)

- Depending on the factors such as the system for securing the PCB or the rigidity of the vibration member, a new resonance system can occur, which adversely affects the accuracy of the acceleration measurement with the shock sensor. Therefore, be very careful to eliminate factors that can affect accuracy.
- Please inquire Murata for washing conditions.

Part Numbering (The structure of the "Global Part Numbers" that have been adopted since June 2001 and the meaning of each code are described herein.)

If you have any questions about details, inquire at your usual Murata sales office or distributor.

Shock Sensors

(Global Part Number) **PK** **GS-25** **ME** **1** **-R**

① ② ③ ④ ⑤

- ① Product ID
- ② Series
- ③ Characteristics
- ④ Individual Specification Code
- ⑤ Packaging

* Global Part Number shows only an example which might be different from actual part number.

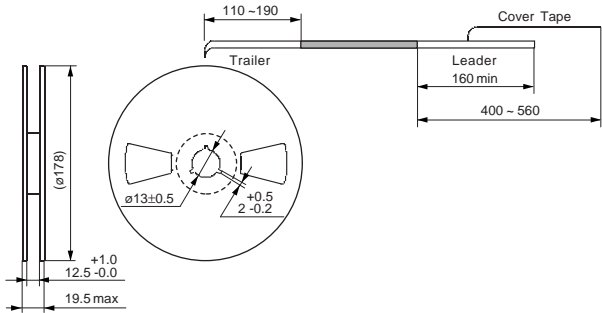
* "③ Characteristics", "④ Individual Specification Code" and "⑤ Packaging" might have different digit number from actual Global Part Number.

Package

■ Minimum Quantity

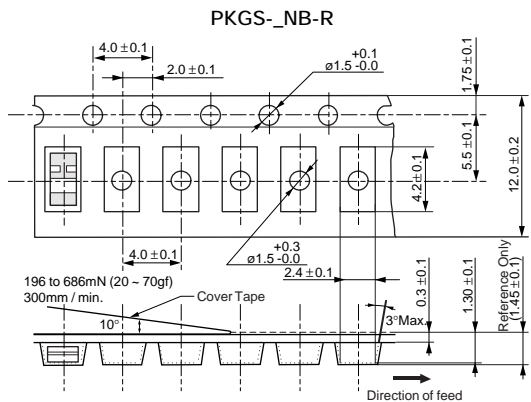
PKGS-_NB-R:180mm dir. reel/3000 pcs.
 PKGS-_MF-R:180mm dir. reel/3000 pcs.
 PKGS-_LD-R:180mm dir. reel/2000 pcs.
 PKGS-_ME-R:180mm dir. reel/3000 pcs.
 PKGS-_LB-R:180mm dir. reel/2000 pcs.
 PKGS-_LC-R:180mm dir. reel/1500 pcs.

■ Dimensions of Reel

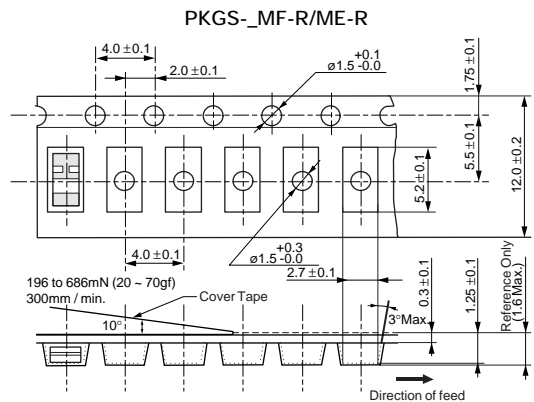


(in mm)

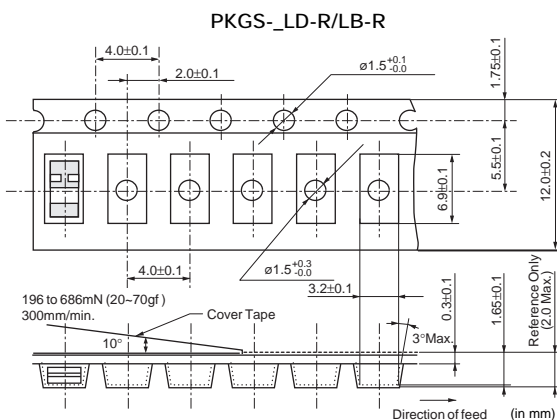
■ Dimensions of Taping



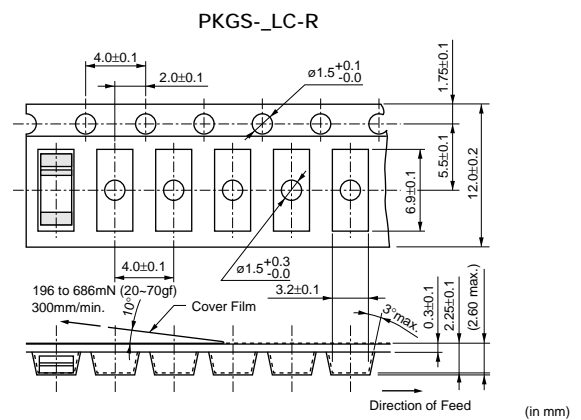
(in mm)



(in mm)



(in mm)



(in mm)

Piezoelectric Ceramic Sensors (PIEZOTITE®)



Shock Sensor

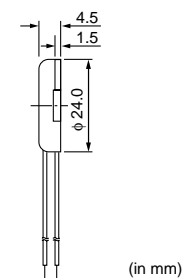
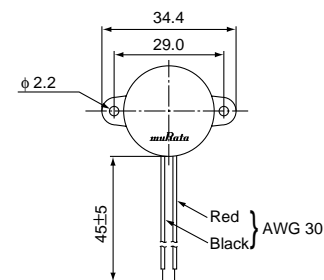
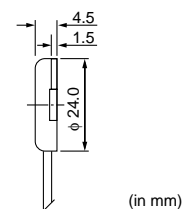
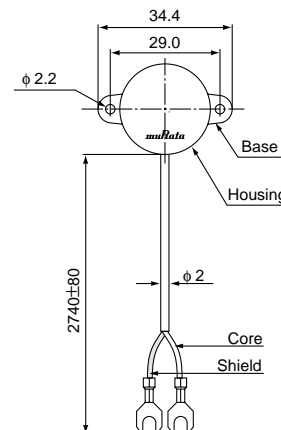
The piezoelectric element produces a voltage which is proportional to the acceleration of an impact or a vibration to which it is exposed. The shock sensor utilizes piezoelectric ceramics to convert the energy of impact into a proportional electrical signal. The piezoelectric shock sensor uses a "unimorph" diaphragm which consists of a piezoelectric ceramic disk laminated to a metal disk. The diaphragm is supported along its circumference in a housing. The sensor features compact, lightweight design, and is suitable for a wide range of applications requiring impact and vibration sensing.

■ Features

1. Compact, lightweight design.
2. High sensitivity assures it picks up even microlevel impact and vibration.
3. Rugged construction survive impact and vibration stresses.
4. Requires no bias voltage.

■ Applications

1. Car burglar sensors on doors.
2. Intruder sensors at windows or doors.
3. Burglar alarms for showcases and safes.
4. Vibration sensors for car audio equipment

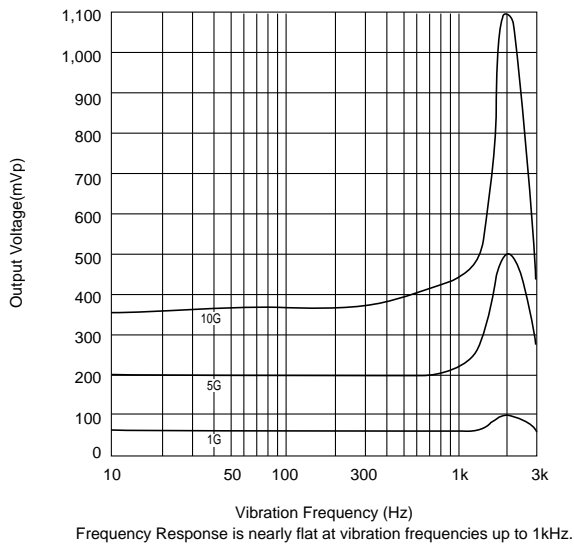


| Part Number | Output Voltage | Capacitance | Insulation Resistance |
|------------------|--|-------------|----------------------------|
| PKS1-4A1 | 40mV0p /G TYP. 4.08mV0p/ (m/s ²) TYP. (at 25°C, 20MΩ Load, 10Hz - 1kHz) | 10000pF±30% | 30MΩmin. (at 100V D.C.) |
| PKS1-4A10 | | 9000pF±30% | |

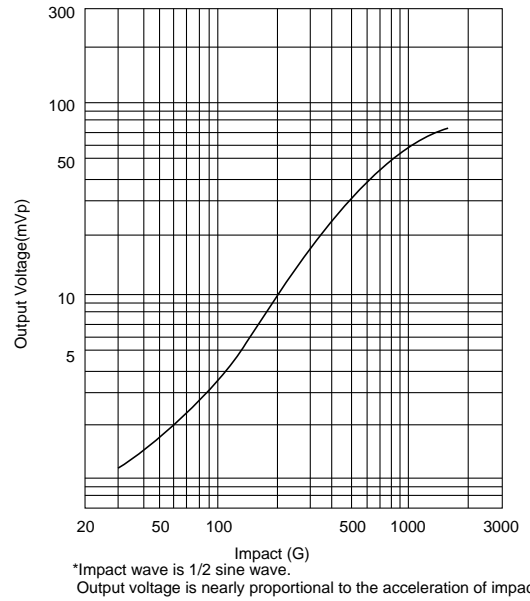
1G=9.8m/s²
Output Voltage is reference value.

■ Characteristics Data

● Frequency Response



● Output Voltage vs. Impact Response



■ Notice

1. The component should be fixed at the place where the main axis of sensor has same direction as the vibration axis.
2. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.

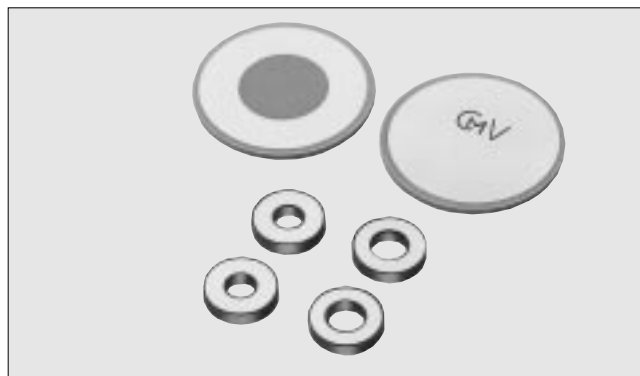
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Piezoelectric Ceramic Sensors (PIEZOTITE®)



Knocking Sensor Elements

The knocking sensor senses abnormal vibrations in an automobile engine. The sensor provides a feedback signal to the engine control system to suppress the knocking. Knocking sensors include a resonant type and a non-resonant type--both of which use piezoelectric elements. Murata offers highly-stable piezoelectric elements for use in knocking sensors which are directly mounted on the engine. Design emphasis is placed on heat-resistant, stress-resistant performance to ensure endurance in the harsh operation environment under the hood. Shape and dimensions are variable according to customer needs.



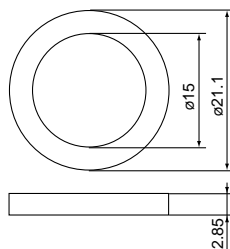
■ Features

1. Provides output voltage proportional to acceleration of vibration.
2. Flat frequency response makes these sensors applicable to any type of engine (for non-resonant type).

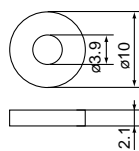
■ Applications

Knocking sensors for automobile engines.

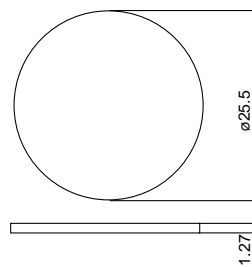
■ Dimensions (Typical value)



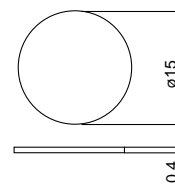
6CC-21-15-700



6CC-10-3R9-1000



7D-25-1600



7D-15-5400

(in mm)

| Part Number | Resonant Frequency (kHz) | Capacitance (pF) | Electromechanical Coupling Coefficient (%) | Applications |
|-----------------|--------------------------|------------------|--|-------------------|
| 6CC-21-15-700 | 66 | 450 | 18 | Non-Resonant Type |
| 6CC-10-3R9-1000 | 180 | 230 | 20 | Non-Resonant Type |
| 7D-25-1600 | 80 | 6300 | 45 | Resonant Type |
| 7D-15-5400 | 137 | 7200 | 55 | Resonant Type |

■ Notice

1. Do not touch the component with bare hand because the electrode may be damaged.
2. The component may be damaged if it is used in any application that deviates from its intended use noted within the specification.
3. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.

Piezoelectric Ceramic Sensors (PIEZOTITE®)



Ultrasonic Bubble Sensor

The ultrasonic bubble sensor emits an ultrasonic wave into a fluid then senses waves reflected from bubbles.

■ Features

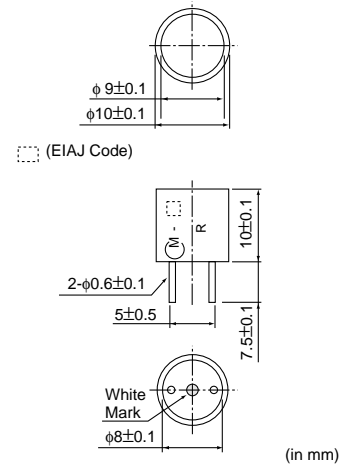
1. Small and light
2. High sensitivity
3. Low power consumption
4. High durability

■ Applications

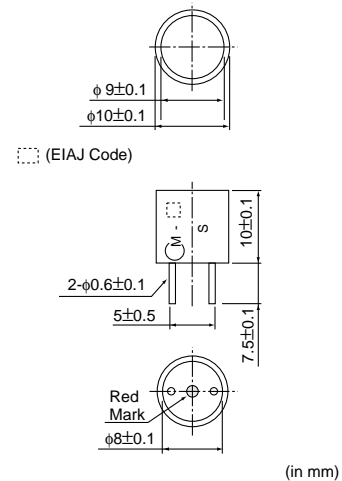
Senses the bubbles or fluids in tubes, e.g. vending machines.



PKH 3-512B1R

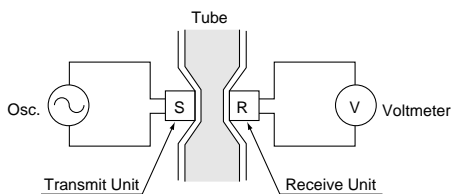


PKH 3-512B1S



| Part Number | Nominal Frequency (kHz) | Capacitance (pF) | Electromechanical Coupling Coefficient (%) |
|-------------|-------------------------|------------------|--|
| PKH3-512B1R | 512 | 280 | 55 |
| PKH3-512B1S | 512 | 220 | 56 |

■ Test Method



■ Notice

1. Please avoid applying DC-bias by connecting DC blocking capacitor or some other way because, otherwise, the component may be damaged.
2. Characteristics can be changed by fixing method. Please contact us.

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Electric Potential Sensors

Every object has its own surface electrical charges or charges given to it from other objects. These electrical charges cause the object to have a certain electric potential with respect to other objects. The electric potential sensor is designed to measure this surface potential.

There are two major surface potential detection methods : The field-mill method and the vibrating capacitance method.

The former method synchronously shuts off the electrical flux from the object surface and modulates the electric field incident to the sensing electrode to induce an AC current on the electrode, proportional to the surface potential (DC). The latter method forms a capacitance across the surface of the object and the sensing electrode, and vibrates the sensing electrode vertically the surface of object to induce electrical charges which are proportional to the capacitance and surface potential, thereby obtaining an AC current proportional to the surface potential (DC).

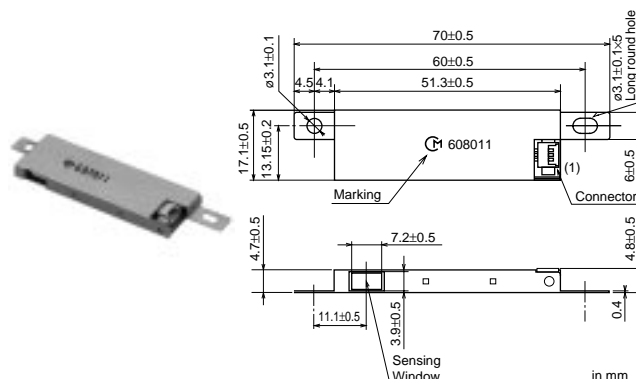
Murata's potential sensors, use a high-precision, piezoelectric tuning fork ("MICROFORK") with a proven production record, to achieve field shut-off vibration and electrode vibration. Integrating all of the signal processing circuit, Murata's electric potential sensor assures high operating stability and reliability.

■ Features

1. Compact, low-profile design.
2. DC voltage output.
3. High-precision linear output and highly stable.
4. Integrates all signal processing blocks, including oscillation, amplifying and rectifying circuit.

■ Applications

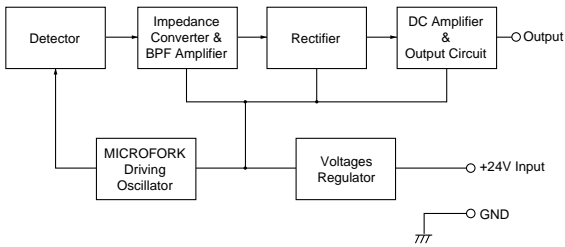
1. Sensing of surface electric potential for photosensitive drums used in PPC machines and laser beam printers.
2. High voltage measurement and detection for high voltage equipment.



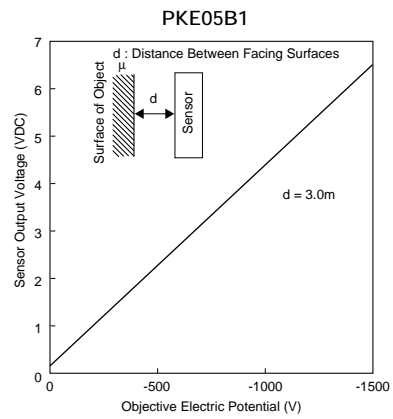
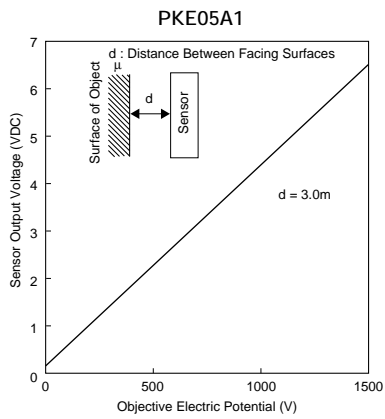
| Part Number | Supply Voltage (Vdc) | Current Consumption (mA) | Min. Detectable Electric Potential (V) | Max. Detectable Electric Potential (V) | Output Voltage | Linearity (%) |
|----------------|----------------------|--------------------------|--|--|-------------------------------------|-----------------------------|
| PKE05A1 | 24 +/-10% | 50 max. | 0 | 1500 | 1/240Vdc of the objective potential | +/-1.5 max.(at 50V~1500V) |
| PKE05B1 | 24 +/-10% | 50 max. | 0 | -1500 | 1/240Vdc of the objective potential | +/-1.5 max.(at -50V~-1500V) |

Operation Temperature Range : 0°C to 60°C Storage Temperature Range : -30°C to 80°C
Detection for negative electric potential are also available.

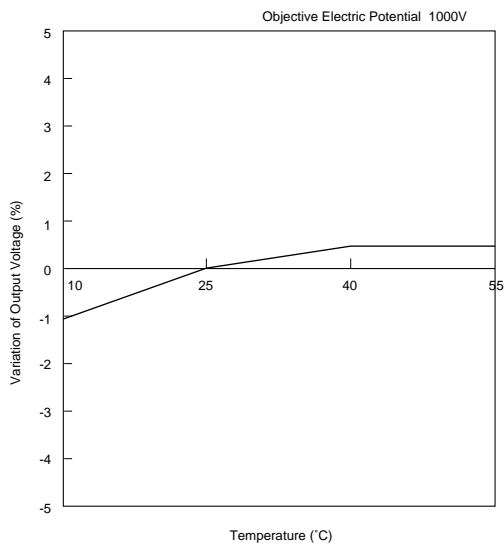
■ Circuit Configuration



■ Output Voltage-Objective Potential



■ Temperature Characteristics



■ Notice (Rating)

Using conditions such as source voltage, temperature range mentioned in this drawing should be kept.

■ Notice (Handling)

1. Electro-static voltage and excessive voltage or reverse voltage may damage the sensor.
2. The sensor should be kept from excessive shock.
3. Please insure the component is thoroughly evaluated in your application circuit because the output voltage and the distance are correlated.

● Part Numbering (The structure of the "Global Part Numbers" that have been adopted since June 2001 and the meaning of each code are described herein.) If you have any questions about details, inquire at your usual Murata sales office or distributor.

Electric Potential Sensors

(Global Part Number)

| | | | |
|----|-----|---|---|
| PK | E05 | A | |
| ① | ② | ③ | ④ |

- ① Product ID
- ② Series
- ③ Characteristics
- ④ Individual Specification Code

* Global Part Number shows only an example which might be different from actual part number.

* Any other definitions than "① Product ID" might have different digit number from actual Global Part Number.

⚠Note:

1. Export Control

⟨For customers outside Japan⟩

Murata products should not be used or sold for use in the development, production, stockpiling or utilization of any conventional weapons or mass-destructive weapons (nuclear weapons, chemical or biological weapons, or missiles), or any other weapons.

⟨For customers in Japan⟩

For products which are controlled items subject to the "Foreign Exchange and Foreign Trade Law" of Japan, the export license specified by the law is required for export.

2. Please contact our sales representatives or product engineers before using our products listed in this catalog for the applications listed below which require especially high reliability for the prevention of defects which might directly cause damage to the third party's life, body or property, or when intending to use one of our products for other applications than specified in this catalog.

- | | |
|-----------------------------|---|
| ① Aircraft equipment | ② Aerospace equipment |
| ③ Undersea equipment | ④ Power plant equipment |
| ⑤ Medical equipment | ⑥ Transportation equipment (vehicles, trains, ships, etc.) |
| ⑦ Traffic signal equipment | ⑧ Disaster prevention / crime prevention equipment |
| ⑨ Data-processing equipment | ⑩ Application of similar complexity and/or reliability requirements to the applications listed in the above |

3. Product specifications in this catalog are as of May 2002. They are subject to change or our products in it may be discontinued without advance notice. Please check with our sales representatives or product engineers before ordering. If there are any questions, please contact our sales representatives or product engineers.

4. Please read rating and ⚠CAUTION (for storage and operating, rating, soldering and mounting, handling) in this catalog to prevent smoking and/or burning, etc.

5. This catalog has only typical specifications because there is no space for detailed specifications. Therefore, please approve our product specification or transact the approval sheet for product specification before ordering.

6. Please read CAUTION and Notice in this catalog for safety. This catalog has only typical specifications. Therefore you are requested to approve our product specification or to transact the approval sheet for product specification, before ordering.

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8. No ozone depleting substances (ODS) under the Montreal Protocol are used in our manufacturing process.